LOST CROPS of AFRICA

volume II Vegetables

Development, Security, and Cooperation
Policy and Global Affairs

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

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Program and staff costs for this study came from the U.S. Agency for International Development, specifically USAID's Bureau for Africa with additional support from the Office of U.S. Foreign Disaster Assistance. Additional funding was received from the Presidents Committee of the National Academies. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

International Standard Book Number-10 0-309-10333-9 (Book)
International Standard Book Number-13 978-0-309-10333-6 (Book)
International Stardard Book Number-10 0-309-66582-5 (PDF)
International Standard Book Number-13 978-0-309-66582-7 (PDF)

Library of Congress Catalog Card Number 93-86876

Additional copies of this report are available from the National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet, http://www.nap.edu

Printed in the United States of America

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Advisers to the Nation on Science, Engineering, and Medicine

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When the idea for a project on native African food plants was first mooted, more than 1,000 people nominated their favorite grains, fruits, nuts, vegetables, legumes, and other plants. All told, over 100 species were suggested for inclusion. Indeed, the numbers and the enthusiasm were so high that we decided to produce separate volumes on grains, vegetables, and fruits. We certainly are grateful to all who helped launch the program, but the following are the ones who especially provided the technical details and insights that created the chapters of this particular book.

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PREFACE

This is the second volume in a series highlighting untapped promise to be found among Africa's traditional food plants. It has been created because within that huge mass of land below the Sahara there exist several thousand indigenous plant species, already selected for food production, that still fall outside the ambit of modern research and economic development. Some are staffs of life for thousands of communities in desperate need of help, so the lack of research attention to them is a disgrace of our times.

The food plants in question are not without merit. Humanity's oldest, they have been feeding people since the beginning. Many thrive in the harsh conditions that many Africans confront daily. And many are exceptionally nutritious. Yet none are receiving adequate scientific or institutional support, despite their significance where the needs for food, nutrition, and rural development are perhaps greater than anywhere else.

We call such neglected foods the "lost crops of Africa." And this abundance of half-forgotten edibles includes hundreds of vegetables. By highlighting a selection of these nutritious gems hidden in plain sight, we hope to stimulate Africa-wide and perhaps worldwide actions that boost their productivity and production, to the advantage of millions now existing at the mercy of fate. Although the project's ultimate aim is to raise nutritional levels, diversify agriculture, and create economic opportunities where all three are most needed, it would be wrong to conclude that Africa's vegetables lack relevance elsewhere. On the contrary, many may offer untold global potential.

It should be understood that the vegetables themselves are in some places very well known. It is mainly to scientists, policymakers, and the world at large that they remain "lost." Such outsiders include of course many in Europe, North America, and elsewhere who influence African research priorities, directly or indirectly from afar. But the outsiders also include science establishments and policymakers within African nations. In this regard it is noteworthy that many sub-Saharan countries allocate their meager agricultural research funds almost exclusively to major international crops that were introduced to Africa in the past.

The current text is designed to reach out to leaders who can direct increased consideration toward the ancestral food plants. In addition, we hope to touch technical experts and open their eyes to the importance of working on these indigenous crops. In the main, though, we hope to inspire

focus on these crops from non-governmental organizations, willing citizens, students looking for research-opportunities, and other enterprising members of the public within the 30-some countries where these vegetables are found in the ground.

In structuring the chapters and selecting the words, we've borne this broad audience in mind. This is why the text has a different feel and form from most scientific publications. Here, we're trying to penetrate an almost universal veil of ignorance by exposing the potential inherent in a collection of overlooked food plants. The information, we trust, will stimulate activities that will provide each plant a chance to achieve the promise still awaiting elaboration in its genes and in the germplasm occupying prime space across Africa.

This book's beginnings go back to a questionnaire that asked Africans and Africa specialists to identify indigenous food plants with unrealized potential. The response was overwhelming; a thousand respondents replied, naming more than 300 personal favorites. Among the nominations were more than 50 vegetables deemed to have unrealized promise of a significant character. From those we chose the 18 highlighted here.[1]

Each description of the selected species begins with an overview aimed at capturing the attention of policymakers, philanthropists, planters, and others having a general interest. The text then proceeds with increasing levels of detail and technical content, aimed at stimulating professional interest among nutritionists, horticulturists, geneticists, and others trained in the various specialties capable of moving the plants solidly into the mainstream of modern endeavor.

These descriptions were initially compiled from literature, queries by mail (and, more recently, email), electronic sources, telephone conversations, and experience gathered through years of dealing with little-known tropical crops. Next we emailed drafts (accompanied by a request for editorial input) to several hundred researchers, most of whom had experience in Africa and more than half of whom were actually there. The response was passionate, and once the new wealth of contributions was incorporated, each redrafted chapter was forwarded to a handful of people (or in some cases many more) who by then we'd learned knew special aspects of that particular plant such as its cultivation, nutritional content, usages, or other relevant information.

With these appraisals in hand, each chapter was yet again reworked to incorporate this round of improvements, including many points not in the prior literature. Following repeated entreaties for clarification of specific points and many rewrites and additional reviews, the results became the crop descriptions making up the body of this volume. While there is no way to

[1] The final selection was to some extent arbitrary—based as much upon available information as on strict scientific assessment. The species set aside could and should fill additional volumes.

achieve full accuracy dealing with such little-known plants, we believe the presentations are balanced and informative.

The book's introductory statements were then composed, based largely on wisdom mined from the reviewers' insights. The combined result was evaluated by a National Research Council panel with deep experience in Africa's agriculture and food problems (see list above). These individuals assessed the relative balance of the manuscript and, in broad terms, evaluated the overall inherent potential of indigenous African vegetables as detailed in the Introduction. The final draft was then reviewed in accordance with procedures approved by the National Academies' Report Review Committee (see below).

These exhaustive processes led to the present volume. It is important to understand that this is neither a textbook nor a technical survey of African botany or agriculture. The writing puts it somewhere between a strictly scientific account and a popular review. As mentioned, we've crafted the message to interest not just specialists but also administrators, entrepreneurs, and researchers unaware of these particular vegetables or their promise.

As already indicated, this is the second in a series. The preceding volume described notable cereal grains found amidst the vast plains, savannas, and deserts below the Sahara. Published in 1996, it covered:

- African Rice (*Oryza glabberima*)
- Finger Millet (*Eleusine coracana*)
- Fonio (*Digitaria exilis* and *D. iburua*)
- Pearl Millet (*Pennisetum* spp.)
- Sorghum (*Sorghum glaucum*)
- Tef (*Eragrostis tef*)
- Other cultivated grains (*Brachiaria*, *Triticum*, *Paspalum*, etc.)
- Wild grains (*Echinochloa*, *Paspalum*, etc.).

A third book accompanies this one. Volume III focuses on African fruits. Its first half highlights 10 cultivated delights:

- Balanites (*Balanites aegyptiaca*)
- Baobab (*Adansonia digitata*)
- Butterfruit (*Dacryodes edulis*)
- Carissa (*Carissa* species)
- Horned Melon (*Cucumis metaliferus*)
- Kei Apple (*Dovyalis caffra*)
- Marula (*Sclerocarya birrea*)
- Melon (*Cucumis melo*)
- Tamarind (*Tamarindus indica*)
- Watermelon (*Citrullus lanatus*)

The second half covers 14 wild fruits:

- Aizen (*Boscia* species)
- Chocolate Berries (*Vitex* species)
- Custard Apples (*Annona* species)
- Ebony (*Diospyros* species)
- Gingerbread Plums (*Parinari* and kindred genera)
- Gumvines (*Landolphia* and *Saba* species)
- Icacina (*Icacina* species)
- Imbe (*Garcinia livingstonii*)
- Medlars (*Vangueria* species)
- Monkey Oranges (*Strychnos* species)
- Star Apples (*Chrysophyllum* and related genera)
- Sugarplums (*Uapaca* species)
- Sweet Detar (*Detarium senegalense*)
- Tree Grapes (*Lannea* species)

The Introduction is laid out so that readers can quickly zero in on plants that may be particularly useful to them. The overall qualities of each vegetable are outlined in brief paragraphs. These are followed by discussions on overcoming malnutrition, boosting food security, fostering rural development, and sustainable landcare, highlighting the potential contribution of each individual species to these development goals. Their overall promise is ranked in a single table (see Table 1) that also shows their general location in Africa.

In the present volume we have abandoned our longstanding habit of appending such things as addresses of research contacts, sources of seed, and technical papers that provide more detail. These days, the Internet is the best place to find such information, which advances too rapidly for print to keep pace. Further, much of the literature on these plants is obscure and of little help to those trying to advance these species; not only does a static list quickly go stale, but much time could be wasted acquiring these sources only to find the same information in a matter of minutes on-line. Our experience is also that printed contact lists quickly become obsolete, misdirecting communications to those who have moved and burdening those no longer engaged, while not representing those newly involved. Circumspection for personal information also pertains to acquiring germplasm, which should only be requested through appropriate channels due to the world's heightened phytosanitary, cultural, and legal concerns.

Although Internet communication is far from satisfactory in much of Africa, advancement during the course of this study has already been astounding, and the ability of those even in the most difficult circumstances

to efficiently access information is impressive. The future of these plants is in collaborative networks of interested workers in Africa and elsewhere freely sharing information and experiences.[2] For such ends, the dynamic possibilities offered by electronically organizing, parsing, and presenting information provide much greater flexibility than the fixed text of the printed page. Much core information on vegetables discussed in this volume is rapidly, or already, appearing online. This new arena allows all to participate and all to benefit.

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report:

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[2] An example of such collaboration is embodied by a network undertaken by the International Plant Genetic Resources Institute (IPGRI): Guarino, L., ed. 1997. *Traditional African Vegetables. Promoting the conservation and use of underutilized and neglected crops*. 16. Proceedings of the IPGRI International Workshop on Genetic Resources of Traditional Vegetables in Africa: Conservation and Use, August 29-31, 1995, ICRAF-HQ, Nairobi. Institute of Plant Genetics and Crop Plant Research, Gatersleben/IPGRI, Rome (online via ipgri.cgiar.org/publications). On a broader scale, prota.org (Plant Resources of Tropical Africa), a joint African/European nonprofit foundation, intends to eventually document 7000 species useful in Africa (both indigenous and introduced), while other Internet sites dealing with these plants, such as ecoport.org, are driven through user input and reciprocal sharing of knowledge.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Calvin O. Qualset, University of California, Davis. Appointed by the National Academies, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authors and the institution.

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Program and staff costs for all these studies came from the U.S. Agency for International Development, specifically USAID's Bureau for Africa with additional support from the Office of U.S. Foreign Disaster Assistance. We are especially grateful to Tim Resch, Michael McGahuey, Ray Meyer, and Laura Powers, all of USAID, for their confidence and perseverance during this project's prolonged confinement and laborious delivery.

How to cite this report:
National Research Council. 2006. *Lost Crops of Africa. Volume II: Vegetables*. The National Academies Press, Washington, D.C.

A NOTE ON TERMS

Throughout this book the word "Africa" always refers to "Africa south of the Sahara."

The plants, too, are sub-Saharan. North African species, being biogenetically part of the Mediterranean-Near East complex, were generally ignored.

We refer to the vegetables by common names rather than scientific ones. This simplifies communication in a book written more for generalists than for specialists.

We have preferred to use English common names where possible, except where they imply that a plant pertains only to one locale or ethnic group (e.g., Hausa potato). An exception is Bambara bean, known as such across the continent. In other cases, however, we have not hesitated to suggest uncommon but more alluring names. A harsh sounding or off-putting name can be a body blow to the advancement of an otherwise excellent vegetable.

The local-name lists that appear in the chapters are not by any means exhaustive. They are included only as a rough help in pinpointing the plant being described.

Unless noted otherwise, nutritional values given are presented on a dry-weight basis to eliminate moisture differences between samples. We depend on reported values, many of which are old or incomplete or otherwise questionable, and which may never have been independently verified. Each species deserves modern verification.

We frequently refer to vitamin A or equivalents—notably when discussing the nutrition of each vegetable. It should be understood, however, that vitamin A is formed in our bodies. Within the plant, it occurs as provitamin A carotenoids. Modern protocols for measuring the levels have rarely been applied to these plants.

Because this book will be employed in regions beyond Africa, we have in most cases used internationally recognizable names when referring to non-African crops. Examples include peanut for groundnut, papaya for pawpaw and cassava rather than its more common African name, manioc.

A WORD TO READERS

Everyone who works with plants assumes responsibilities. Some species described in this report—especially those which are less than domesticated—may be pestiferous or invasive outside their natural environs, and thus require due caution and on-going scientific assessment after introduction. Unless professionally inspected, they may also carry along unseen pests and diseases (particularly small insects and microbes such as virus or bacteria) whose populations might explode catastrophically in new locations. In addition, plant genes and germplasm are subject worldwide to both tangible- and intellectual-property laws; these legal rights hold especially true for food plants in which others—whether farmers or financiers—have already invested thought and labor or capital. For these reasons, most nations have official protocols based on intergovernmental conventions governing the safe and legitimate transfer of plant materials. These protect both people and the environment, and are rarely any obstacle to helpful activities. In the best interest of all parties, it is crucial that the requirements of such protocols be strictly followed.

FOREWORD

The great thing about the edibles highlighted here is that they can be used for probing the heart of Africa's most basic problems—hunger, malnutrition, rural poverty, environmental destruction. Collectively, they have the power to pump rich new nutrition into what is now an anemic food supply, sputtering rural economy, uncertain public health, and less-than sustainable farm operations.

Some people argue that these problems are but symptoms arising from deeper evils associated with low levels of economic productivity. Yet on that score too, edibles highlighted in the following pages can help. In theory at least, they can expand opportunities and contribute to the resuscitation of prosperity across rural Africa—locales where human life has in recent decades suffered hardest.

Another thing, no less great, is the fact that these vegetables offer ways by which people throughout the continent can work together for a common good. Fundamental, too, is cooperation between those who know tradition and those who know technology. Non-Governmental Organizations might make all the difference in building those bridges. The NGO proliferation is a change from the past, and for the development of the indigenous vegetables such organizations seem ideally poised to straddle voids between science and society, the past and the future, Francophone and Anglophone locales, and technologists the world around. At various levels, small active groups could coordinate, sponsor, manage, direct, or monitor the collection of plant materials, the documentation of traditions, the experimentation within laboratories, and so forth—all in relation to a vegetable of particular merit for the people and the environment they are dedicated to serve.

Indeed, individuals on more fortunate continents can also reach in and help improve the lives of Africans through the advancement of such promising resources as we describe. That notion may seem strange, but in furthering these particular food plants there's scope for almost everyone—regardless of their level of influence, sphere of interest, or place on earth. This is not a novel notion: everywhere else, crops were developed both by outside influences *and* by local actions.

Of course experts in the relevant sciences can make vital advances in getting Africa back to its roots. In furthering any of these crops there's a place for food technology, nutritional analysis, DNA probes, taxonomic identification, toxicological tests, agronomy, horticulture, pathology, vegetative propagation, selection, breeding, and more.

Specialists in such subjects could make a big difference in boosting the better use of native foodstuffs in a continent woefully deficient in such expertise. Every chapter elaborates technical tasks needing attention. And

with today's communications individuals on one side of the world don't have to leave home to champion a crop on the other. Electronic collaborations are increasingly common, and Africa's under-exploited foods seem ideal vehicles for the world's specialists to interact at many levels and in many ways with the world's neediest farmers and lift their meager lives.

Beyond specialized scientific inputs, there's much scope for ordinary folks to figure in the revitalization of rural Africa. Examples include:

- Creating classroom materials and conducting children's gardening projects;
- Learning from local farmers how to master the complexities of growing each vegetable under the prevailing local conditions;
- Reaching out to professionals in subjects such as food technology, nutrition, and horticulture to alert them to African vegetables' needs;
- Setting up websites (which might, for instance, highlight a vegetable or a region's indigenous vegetables or perhaps the use of native produce to counter a problem such as malnutrition);
- Fostering traditional vegetables in university courses, government extension, agricultural fairs, and operations run by foundations, foreign governments, development banks, and the rest;
- Coordinating the collection of a lost crop's seeds, locally, nationally, regionally, or perhaps internationally;
- Translating documents such as this one into local languages or translating scientific papers to-and-from especially French;
- Compiling country profiles of a lost crop, including regional recipes, beliefs, stories, management methods;
- Running an email alert service to pass on the latest news relating to these resources as advances emerge worldwide;
- Developing and adapting processing, storage, and transportation technologies;
- Organizing web-links among institutions and individuals working on Africa's "lost crops"
- Establishing a cyber-exchange linking suppliers of African crop products to marketplaces around the world;
- Developing new recipes incorporating them into different cuisines;
- Searching colonial-era archives (those housed locally as well as others in Europe) for any previous investigations;

- Recording these crops' myriad vernacular names and uses; or
- Providing a forum for swapping or selling seeds or other planting materials in an open, ethical exchange.

As we've said, we hope our words will stimulate such actions and lead to a wider, wiser, older, newer, and sounder sub-Saharan food supply. We think that, with commitment, the rewards to any reader stimulated into action could be legion. Involvement with any of these vegetables can touch the hearts of the humans most needing a hand up. For Africa, these species represent some of the best foods for the future. They also represent some of the best science projects. Although generally ignored by researchers, many of these crops are quite familiar in farms, gardens, markets and, in some cases, thousands of square kilometers of hillsides and savannas. Most are suited to the small plots, mixed cultivation, poor soils, local diets, and time-honored lifestyles of family or village. To have survived into modern times without "official" intellectual support indicates something about their inner strengths.

Taken all round, then, these lost crops constitute an obvious, though not necessarily simple, way by which Africa can reach back to the past and help fashion *for itself* a future.

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INTRODUCTION

It might be supposed that a hungry continent would exploit all its available food plants to the fullest, but in Africa's case that is not so. The region below the Sahara is home to hundreds of contributors to the food supply, almost none of which is currently accorded scientific support, official promotion, or inclusion in development schemes.

In the beginning, Africa's edibles fed humanity. The earliest emigrants out of Africa—long before agriculture—found new foods on their journeys, but at home there was a contraction of agrodiversity as farming increasingly focused attention on those plants most practical as mass-suppliers of food in the greatest number of places. Still and all, for many thousands of years, hundreds of wild and (in time) cultivated native species complemented each other to comprise the core of the continental food supply.

Then before recorded history, a pivotal plant migration began as a few Asian foods wended westward to become new links in the African food chain (sorghum and others took the return route from Africa). They arrived partly thanks to increasing trade between India and Africa's eastern seaboard, as well as overland and perhaps even through surprising long-distance connections between Madagascar and today's Indonesia. Exotic species from Asia—most notably rice, bananas (in their various forms), and sugarcane—began contributing more and more to life below the Sahara.

Yet many Africans remained largely dependent on traditional food plants until about five centuries ago, when adventurers and slavers sailing the western seaboard introduced a collection of American crops. These additions notably included maize (corn), cassava (manioc), peanut (groundnut), sweet potato, tomato, common bean, chili peppers, and pumpkin. As is common with nonnative plants, the new arrivals tended toward robust and productive growth, and subsequent centuries saw them spread across Africa as farmers integrated these helpful adjuncts into their age-old livelihood strategies. That inevitably meant that more of the traditional contributors fell away from the food supply and the minimization process proceeded.

During the colonial era the process of discarding indigenous crops gained further momentum, as the official focus shifted to those familiar crops of mercantile interest, such as cane, chocolate, coffee, cotton, and other durable, transportable, and valuable crops of that sort. Indeed, during those times subsistence crops were almost entirely neglected in organized agriculture, while valuable exportable cash crops were cultured, harvested, graded, and protected against rodents, insects, and decay with exceptional

efficiency and dispatch. And an end result of these historical trends was that most of Africa's food these days comes from a mere 20 or so species, almost all of foreign extraction.

Like grains and fruits, Africa's ancient vegetables were vulnerable to the sweep of these events. Long ago, hundreds of leaves, roots, tubers, corms, rhizomes, bulbs, seeds, buds, shoots, stems, pods, or flowers were eaten. Yet across Africa today the main vegetables are crops such as sweet potato, cooking banana (plantain), cassava, peanut, common bean, peppers, eggplant, and cucumber. Countries in the elevated central regions—Burundi, Rwanda, Ethiopia, and Kenya—grow potato. Banana dominates Rwanda, and Ethiopia also relies on chickpea and lentil. And South Africa records its leading vegetable crops as potato, tomato, green mealies (maize), sweet corn, onion, pumpkin, carrot, cabbage, lettuce, and beetroot.

The disconnect in such modern-day enumerations is that these "African" vegetables come from Asia or the Americas. Indeed, a popular textbook on vegetables in Africa features about 100 species, only 3 of which are native born. Out of the continent's top vegetables today, only cowpea, yam, and okra are African.

This situation is not, in itself, a major detriment. The United States, after all, has almost half of sub-Saharan Africa's population and eats essentially no local food plants whatsoever.[1] But unlike the United States, Africa needs more and better food. And unlike America, which is biologically deprived of native food plant abundance, Africa also has the blessing of hundreds of worthy candidates waiting in the wings—the old ones that during the course of history got dropped from the food supply not through insufficient merit but through the negligence or priorities of eras now past and for reasons no longer relevant.

There are lessons to be learned from such history. Many foods of the utmost importance today were bypassed in the past because they were considered "poor people's plants." Peanuts, potatoes, and many other top-line crops once suffered this discrimination. In the United States the peanut was scorned as "merely slave food" until little over a century ago, and in the 1600s the English refused to eat potato on the basis that it was "Irish food." The list is lengthy, and cultural bias against peasant crops is an ultimate calamity because plants that poor people grow are usually robust, productive, self-reliant, and useful—the very type well-suited to feeding the hungriest and most vulnerable sections of society.

Surely the door is now open to a renaissance of Africa's vegetable resources. Sadly, though, even in our times, such historical exclusionary trends continue. The imbalance between the traditional and the introduced species, already worrisome, continues tipping toward an even greater

[1] The only food crops native within the U.S. borders are minor contributors, such as sunflower, Jerusalem artichoke, Concord grape, pecan, cranberry, and small fruits like blueberry and raspberry.

reliance on other people's plants. More correctly, it is tipping against the use of, and appreciation for, the traditional vegetables that have fed Africans for tens of thousands of years. While science makes the top resources better, the lesser ones fall farther behind, shunting the vast majority of the cuisine into anonymity, if not extinction. This means most of Africa's own edibles have yet to receive due attention, let alone a chance to develop to their potential under the power and promise inherent in modern capabilities.

The global homogenization of lifestyles is not fully to blame for squeezing out traditional vegetables, for modern connections and wealth have also led to an explosion in the availability of novel foods in every developed market. Rather, to a considerable extent this neglect seems to be an unintended consequence of agricultural successes in research-rich regions. And not unnaturally, Americans, Europeans, Asians, and others see Africa's future in the vegetables they themselves depend upon. Thus soybean and the rest garner the research spotlight, rise to ever-greater levels of food and cash generation, and seem thereby to justify even more research support.

Something of this scientific spiral can be deduced from the amount of research now dedicated to soybean. By comparison, Africa's yam and okra can hardly be said to get any support at all; even cowpea, probably the best-funded of all African vegetables, falls far short of a soybean standard. Indeed, it is no coincidence that the continent's top three traditional vegetable resources basically languish while their foreign counterparts seize ever more momentum within the lands to which cowpea, yam, and okra have contributed with distinction for millennia. And beyond those three "visible" African vegetables lies a huge array of "invisibles," whose names remain unknown in the world's leading vegetable research institutions and which as a consequence get left without support. An irony that demonstrates the potential for such "lost" African crops is that soybean itself was little-known outside Asia a century ago, yet within a lifetime it has become a crop of global heft.

Emphatically, to the extent soybean can benefit Africa, research support is a very good thing. Competition is as healthy in crops as it is in commerce, and there will always be losers. However, to feed a continent as vast and diverse as this requires more and better adapted food crops. That in turn points to the age-old vegetables, feeding people long before Africans discovered Asia, Europe, and America; these "lost crops" should be included among Africa's future options.

When compared with the ancient stock of modern crops, these traditional African food crops remaining outside the fold of science have not been rejected because of any inherent inferiority. It is time to open minds to the power and promise of this indigenous edible wealth. It is not that the ancestors' vegetables should be placed in the forefront of efforts to feed Africa, but they deserve to be pulled out of anonymity and given a fair

chance to expose their worth to modern times. Many have important contributions to make today, and eventually—if merited—they may move on a path leading toward a well-fed continent.

Now is the opportunity to explore Africa's future in the promise of its edible botanical wealth. These days researchers are enthusiastic about genetic engineering and the new products to arise from it. This emerging technology offers promise for Africa, but enthusiasm must not obscure the fact that huge numbers of nature's organisms—already selected and improved by humans—have yet to be explored by the "traditional" scientific methods that have proven nearly miraculous at improving global food production for decades on end. Some little-known local plants may have a genetic makeup so outstanding that they could help solve some of Africa's–not to mention the world's–most pressing food problems.

Beyond all that, a revitalized development of Africa's own food plants could open new windows of opportunity beyond those agriculturists normally imagine. In principle, these domesticates can help not only feed an increasing population, but also make marginal lands more productive, lift rural incomes, and re-clothe denuded and desolate areas. Moreover, they can widen the continent's agricultural resource base, fashioning a food supply that is not only more stable but more secure. The genes for fighting off the ravages of pests and diseases may already be available. Indeed, this endeavor seems ideally suited as a mission for Africa's own under-utilized agricultural science.

But with which native vegetables should the revitalization process start? Even within living memory Africans still ate an astonishing number of different plant products. One writer lists 83 species used as vegetables just in what is today Zimbabwe. In one small part of South Africa more than 120 species were until recently common vegetables. Large 19th and 20th Century tomes (targeted largely toward scholars) were written in both English and French detailing hundreds of plants consumed daily in West Africa. Even in the arid areas of Namibia and Botswana, where environmental extremes limit options, one observer lists 18 vegetable-like plants eaten by traditional cultures in the blistering heart of the Kalihari.

It is conceivable that 3,000 native African roots, stems, tubers, leaves and leafstalks, bulbs, immature-inflorescences, and fruit-vegetables were eaten routinely. But knowledge of what can and cannot be eaten was generally passed through generations from mother to daughter and from child to child. This direct, personal, on-the-scene tutoring was effective, but taking advantage of it today is fraught with difficulty. Though some of the knowledge has been recorded, sadly much of that experience has faded from the collective memory. Merely knowing that a species was eaten is not as helpful as might be supposed, and nowadays it may be difficult to glean from the overall genepool those especially palatable specimens that were the only ones used in the past.

Yet not all is lost. Many indigenous edibles are still widely cherished across Africa today. Some are even attracting resurgent research interest. A few ground-breaking growers and creative researchers have become intrigued by these ancient resources. Indeed, plant champions Africa-wide consider that—given attention—these ancestral foods have a capacity to take their place alongside the modern marvels dominating today's textbooks, scientific treatises, and the international image of what a first-class vegetable should be.

Besides offering an important opportunity to diversify the food base, the traditional crops lend themselves to local initiative, not to mention local sentiment. Africa's own researchers and growers could lead the charge to reinvigorate these ancient resources. It is also noteworthy that advances in plant breeding, genetics, and increasingly genomics will transform these ancient and neglected resources far faster than might seem likely based on historical precedent. Generally, it is no longer necessary to invest centuries to bring a crop to its potential. Given even a little attention and support, Africa's fruits and vegetables could quickly contribute even more to the environments, nutrition, economies, and personal income–particularly women's income–of many if not most African nations.

This then is a good time to be peering past the current commercial crops and developing a complementary set of contenders. That is already happening in "post-industrial" nations, where markets abound with a cornucopia of vegetables not seen twenty years ago. For Africa, its own "lost" species are an obvious place to begin that same sensible process of diversification to meet the needs of today and beyond.

SUMMARIES OF INDIVIDUAL SPECIES

Following are summaries of the vegetables selected for treatment in this volume. Seen in overall perspective, these native resources could provide much more than food. They promise to lift the quality of life throughout the continent that needs it most. Their individual possibilities to address pressing problems of nutrition, food security, rural development, and the enviroment in Africa are focused upon in Table 1 and the sections following the 18 summaries below. Please note that the information in these summaries can also be found in the individual species chapters as well.

1. Amaranth

Vegetable amaranths (*Amaranthus* species, Amaranthaceae) are arguably the most widely eaten boiled greens throughout Africa's humid lowlands. During the production season they reportedly provide some societies with as much as a quarter of the daily protein intake. The tender young seedlings are pulled up by the roots and sold in town markets by the thousands of tons annually. In addition, the leaves and stems from full-grown plants make boiled vegetables with soft texture and mild flavor. All this has come about despite an almost total lack of formal development or official support. Given professional attention, these fast-growing vegetables could contribute even more vitally to nutrition, food security, and rural prosperity—especially the prosperity of rural women, who are the major producers.
Climate Humid lowlands, dry savannas, uplands.

2. Bambara Bean

Seeds of this legume (*Vigna subterranea*, Leguminosae) are dug from the ground like peanuts. Typically, they are then boiled, roasted, or fried, ground into flour, and blended into many traditional dishes. Despite an almost total scientific neglect, nothing fundamental appears to be stopping this especially appetizing crop from much greater contributions to the diet of much of Africa. It produces a food of exceptional nutritional quality, so a little goes a long way toward building and maintaining a solid foundation of good health. All in all, this tasty protein-rich bean promises to benefit the people most in need and hardest to reach through conventional development programs.
Climate Humid lowlands, dry savannas, uplands.

3. Baobab

The leaf of the much beloved baobab (*Adansonia digitata*, Bombacaceae) is a staple of the savanna lands below the Sahara. In an area stretching across half the continent this vegetable ranks among the commonest foods.

Bursting into foliage a little before the rains begin, the stately trees remain green and edible until a little after the rains have ceased months later. The leaf is sometimes steamed and eaten as a side-dish like spinach, but most goes straight into soups, stews, sauces, relishes, and condiments that complete the main dish of the day.

Climate Mainly dry savannas.

4. Celosia

The prettiest of all vegetable crops, celosia (*Celosia argentea*, Amaranthaceae) is used as an ornamental almost everywhere on earth. But few of its millions of admirers know that it is a common item of diet in parts of tropical Africa. The fresh young leaves, young stems, and young flower spikes are used to produce a tasty and nutritious "soup" that is a daily fare especially in West Africa. Productive and simple to grow, the plant could in the future become a much greater contributor to African welfare, especially in the hot and poorly nourished regions of the equatorial zone.

Climate Humid lowlands, uplands.

5. Cowpea

Although globally obscure, cowpea (*Vigna unguiculata*, Leguminosae) is grown by tens of millions of smallholders in Africa. West Africans alone plant an estimated 6 million hectares annually. In fact, it is estimated that 200 million children, women, and men live off the plant—consuming the seeds daily whenever available. Widely appreciated by the poor, cowpea seed is not only rich in protein but in digestible carbohydrate too. Although not strictly a "lost crop" (it traveled long-ago to South Asia, where it expanded into an important asset), it still falls far short of its potential. Indeed, that potential could be very high because this species seems strong enough to lift Africa's overall food quality.

Climate Primarily dry savannas and uplands.

6. Dika

Throughout a giant triangle from Senegal to Uganda to Angola, dika (*Irvingia wombolu* and *Irvingia gabonensis*, Irvingiaceae) is a part of the daily diet. Although this tree's fruits are popular in some areas, the seed is the major resource. These so-called "dika nuts," which are something like cashews, can be eaten raw or roasted. Most, though, are ground and combined with spices to form the key ingredient in "ogbono soup," a spicy dish extremely popular among West and Central Africans. As a result, this so-far-undomesticated tree scores high on the list of species inhabitants hope to see developed.

Climate Humid lowlands, dry savannas, uplands.

7. Eggplant (Garden Egg)

This vegetable (*Solanum aethiopicum*, Solanaceae), like its better-known Asian cousin (*S. melongena*),. provides brightly colored egg-shaped fruits that are a significant vegetable resource almost Africawide. The species is high yielding, easy to grow, and simple to harvest and handle. It is integral to many cuisines, cultures, and economies. Yet in many parts of Africa there is considerable scope for producing much better varieties in much better quantities.
Climate Humid lowlands, dry savannas, uplands.

8 Egusi

Egusi is a melon-like crop grown for its large white seeds, which in West Africa are a component of many meals. The plants themselves are from several species and genera, notably including watermelon itself (*Citrullus lanatus*, Cucurbitaceae). Ground up coarsely, the seeds thicken stews and contribute to a widely enjoyed steamed dumpling. Some are soaked, fermented, boiled, and wrapped in leaves to form a popular seasoning. They are also roasted and made into a spread not unlike peanut butter. They are even compacted into patties that serve as a meat substitute. Seen in overall perspective, this is a versatile crop with valuable for both subsistence survival and modern commerce.
Climate Humid lowlands.

9. Enset

Although few outsiders have ever heard of it, this tree-like herb (*Ensete ventricosum*, Musaceae) underpins the food supply in Ethiopia's densely populated highlands. An estimated 10 million people consume it. The plant is perhaps the biggest vegetable of all and looks like a banana "tree." The food, however, comes mainly from the trunk, which on the largest specimens can be a meter in diameter and three meters tall and is filled with starchy pith. A second food comes from underground, where can be found a corm that may be almost a meter long and a meter in diameter and is packed, like some giant potato, with starch. Any plant producing food by the cubic meter is surely something to use more intensively in a hungry continent, but so far this one is barely known to science, let alone to Ethiopia's neighbors.
Climate Upland.

10. Lablab

In Asia lablab (*Lablab purpureus*, Leguminosae) is a popular foodstuff. For the rural peoples of southern India, for instance, its pods and seeds supply much of the daily protein. The strange thing is that lablab is African. Stranger still is the fact that it is almost unknown in present-day Africa. Yet

this clambering bean possesses qualities that could prove exceptionally valuable for nutritional well-being, rural development, and environmental stability in almost every corner of its continent of origin.

Climate Humid lowlands, dry savannas, uplands.

11. Locust Bean

Another legume, the West African locust bean (*Parkia biglobosa*, Leguminosae), grows more than 20 meters tall. Its pods, which dangle all over the tree's spreading crown, contain seeds as well as a dryish pulp that can be half sugar. The seeds are gathered by the thousands of tons and peddled by itinerant traders throughout West Africa, often as a medicinal. Chiefly, they are fermented into the famous dawadawa. This sticky, sour, cheesy solid is rich in protein, vitamins, and food energy and even in the tropical heat it keeps well without refrigeration. Dawadawa is exceptionally popular as a seasoning, but it is also an important soup ingredient. This single species, which has received almost no horticultural recognition, combines likely answers to Africa's twin needs of food and tree cover.

Climate Dry savannas.

12. Long Bean

This delightful legume (*Vigna unguiculata*, Leguminosae) resembles a snap bean except for the singular fact that it is pencil-thin and up to a meter long. Often called yardlong bean in English, its green to pale-green pods are tender, stringless, succulent, and sweet. The surprising thing about what is universally acclaimed an "Oriental vegetable" is that it is a special form of cowpea—a species of unquestioned African origin (see cowpea, above). Now is the time to welcome long bean back home to contribute as much to Africa as to Asia.

Climate Humid lowlands, dry savannas, uplands.

13. Marama

Above ground, this plant (*Tylosema esculentum*, Leguminosae) produces seeds rivaling peanut and soybean in nutritive quality. Below ground, it produces a high-protein tuber much bigger even than sugar beet and much more nutritious even than potato or yam. The plant thrives in poor-quality soil and under the harshest of climates. Indeed, in its native habitat, the deserts of southern Africa, rain often stays away for years on end. But this seems a resource more in theory than reality; it is undomesticated and has far to go before anyone can truly capitalize on such valuable qualities.

Climate Semiarid lands.

14. Moringa

Yielding protein, oil, and carbohydrates, and with a lode of vitamins and minerals, moringa (*Moringa oleifera*, Moringaceae) is possibly the planet's most valuable undeveloped tree, at least in humanitarian terms. A sort of food market on a stalk, it yields at least four different edibles: pods, leaves, seeds, roots. And beyond edibles, it provides products that make village life more self-sufficient: lubricating oil, lamp oil, wood, paper, liquid fuel, skin treatments, the means to purify water, and more. The green pods, which look like giant green beans but taste something like asparagus, are notably nutritious. Foliage is an important food product as well. People in various countries boil up the tiny leaflets and eat them like spinach. Taken all round, this supreme poor-person's plant shows a remarkable capacity to help solve problems such as hunger, malnutrition, rural poverty, disease, deforestation, and visual blight. Although the experiences come almost exclusively from India, the genus *Moringa* is inherently African, so it has ancestral roots in the sub-Sahara soil.

Climate Humid lowlands, dry savannas, uplands.

15. Native Potatoes

Africa's native "potatoes" (especially *Solenostemon rotundifolius* and *Plectranthus esculentus*, Labiatae) are actually members of the Mint Family. Smaller than modern commercial potatoes, their tubers hang in bunches from the base of the plant. They are mostly boiled, but can also be roasted, baked, or fried. Despite kinship to pungent herbs like basil, mint, sage, and thyme, the tubers have a bland taste and can replace potato in most recipes—including potato salad. Not only are they nutritious, they are productive. Even in their current fairly unimproved form, native potatoes can produce a lot of food from a small area. And they seem primed for rapid advancement to a major African resource.

Climate Humid lowlands, dry savannas.

16. Okra

A perfect villager's vegetable, okra (*Abelmoschus esculentus*, Malvaceae) is robust, productive, fast growing, high yielding, and seldom felled by pests and diseases. It adapts to difficult conditions and can thrive where other food plants prove unreliable. Among its useful food products are pods, leaves, and seeds. Among its useful non-food products are mucilage, industrial fiber, and medicinals. Seen in overall perspective, this often-derided resource could be a tool for improving many facets of rural life. Its production and maintenance is fairly well known in the U.S. and elsewhere, and this offers the possibility of rapid advancement within Africa.

Climate Humid lowlands, dry savannas, uplands.

17. Shea

Although few outsiders know this tree, shea (*Vitellaria paradoxa*, Sapotaceae) remains among West Africa's most extensive food sources. West Africans employ its smooth-skinned, egg-shaped nut much like Westerners employ lard and butter. For a vegetable lipid this one is strange in that it remains solid even under tropical conditions. Countless Africans also use it for skincare, and these days shea butter is going global and going upscale as an ingredient in some of the most expensive cosmetics ever formulated.

Climate Dry savannas.

18. Yambean

The African yambean (*Sphenostylis stenocarpa*, Leguminosae) is a legume grown mainly for its fleshy swollen roots, which look something like sweet potatoes but are succulent, sweet, and crisp as a fresh-picked apple. In nutritional terms, they are a class above the mainline root crops, containing more than twice the protein of sweet potatoes, yams, or potatoes and more than ten times that of cassava. Moreover, the protein is of exceptional nutritional quality, superbly complementing the proteins of maize, sorghum, and the other staples. In addition, both seeds and leaves are edible. And the African yambean is no slouch in the yield department, either. It produces its edibles in abundance, and seems capable of delivering record quantities of protein from soils normally considered marginal.

Climate Humid lowlands and uplands.

TABLE 1: POTENTIAL ROLES FOR SELECTED AFRICAN VEGETABLES

****** = Outstanding; ** = Notable; * = Average***	Overall	Nutrition	Food Security	Rural Development	Sustainable Landcare	PRIMARY OCCURRENCE			
						West Africa	Central Africa	East Africa	Southern Africa
Amaranth	**	***	**	***	*	√	√	√	√
Bambara Bean	***	***	***	***	**	√	√	√	√
Baobab	**	**	***	***	***	√	√	√	√
Celosia	**	*		*	*	√			
Cowpea	**	***	***	**	**	√	√	√	√
Dika	**	**	*	***	***	√	√		
Eggplant (Garden Egg)	**	*	**	**	**	√	√	√	√
Egusi	***	***	**	***	**	√	√		√
Enset	*	*	***	*	**			√	
Lablab	***	**	**	***	***	√	√	√	√
Locust Bean	**	**	***	**	***	√			
Long Bean	***	**	*	***	**	√	√	√	√
Marama	*	*	*	*	*				√
Moringa	***	***	**	***	**	√	√	√	
Native Potatoes	*	**	**	**	*	√	√	√	√
Okra	**	**	**	***	**	√	√	√	√
Shea	***	*	**	***	***	√			
Yambean	**	***	**	*	***	√	√	√	√

NB: The underlying justifications for these broad rankings are discussed in the following sections on Nutrition, Food Security, Rural Development, and Sustainable Landcare; greater detail is provided in the separate chapters on individual crops.

POTENTIAL ROLES FOR SELECTED AFRICAN VEGETABLES

To give some idea of their potential to help solve the great central issues of African humanitarian and economic development, we now highlight the relevance of the above-mentioned vegetables to four of Africa's biggest needs for human survival and social serenity: 1) nutrition, 2) food security, 3) rural prosperity, and 4) general landcare. Supporting evidence can be found in the respective chapters.

OVERCOMING MALNUTRITION

These days there is increasing appreciation for the class of food we call vegetables. Evidence is rising on all sides that a lack of vegetables increases susceptibility to infection and disease as well as to stunted physical and mental growth. Vegetables also help palliate the scourge of Africa's major health problems that are today exacerbated by the lack of a balanced diet.

By and large, vegetables supply dietary elements in which other food materials are deficient. For one thing, they are prime sources of minerals, being typically rich in calcium and iron and also contributing phosphorus, potassium, copper, magnesium, manganese, and cobalt. A few vegetables—notably legumes, such as various beans—are valuable sources of proteins. Furthermore, their cellulose, an indigestible carbohydrate, absorbs water and provides the bulk material, or roughage, that promotes intestinal function.

For another, vegetables are important sources of vitamins. Vitamin C, vitamin A, and folic acid are what make them essential to human well-being, but most vegetables also provide other B vitamins, including thiamine (B1), riboflavin (B2), pantothenic acid (B5) and pyridoxine (B6), which are important for brain function, immune-system operation, and the production of several important hormones. Many vegetables also contain small but useful amounts of vitamin E.

By choice or circumstance, the diets of many African communities are deficient in vitamins, minerals, and other nutrients vegetables supply. Through research and extension of traditional vegetables, much could be done to change the situation…cheaply and rapidly. Seen in Africa-wide perspective, this is likely to be at least as effective as any move to "biofortify" cereal grains.

It seems worth mentioning here that much can be achieved through school gardens, where children learn about growing vegetables while at the same time also attaining a better level of nutrition. Traditional vegetables would be worthy components of such enlightened school projects, supplying lessons far beyond the dignity of dirty fingers.

Below is a summary of the merits, *specifically in terms of fighting malnutrition*, of each of the 18 vegetables this book highlights. Additional

information, when available, is given in the separate chapters, but in general nutritional details for these crops are limited and at times of doubtful usefulness because of outmoded techniques. Even those vegetables for which there are no data are likely to have nutritional values in common with most vegetables.

Amaranth

In overall nutritional power, amaranth greens are not dissimilar from the better-known leafy vegetables. Their exceptional protein quality, however, makes them useful supplements to cereals and root foods. For this reason, India has been known to fortify weaning foods with amaranth-leaf flour. Moreover, the leaves are packed with vitamin A-forming carotenoids, whose lack blinds thousands of children each year. In addition, the leaves provide vitamin C and tend to accumulate dietary minerals, notably iron and calcium. All this puts amaranth greens among the finest potherbs for reducing the ravages of nutritional deficiencies.

Bambara Bean

Bambara bean is a rare examples of a complete food. It has such a nice balance of nutrition that people supposedly can live on it alone. Ripe or immature, the seed is roughly 60 percent carbohydrate, 20 percent protein, and 7 percent oil. In addition, the protein contains more of the nutritionally essential amino acid methionine than almost any other bean, making this peanut-like bean even more valuable. For these reasons this crop could be a superb tool for attacking Africa's under-nutrition.

Baobab

Baobab leaf provides at least three nutritious ingredients: protein, vitamins, and minerals, not to mention dietary fiber. The protein is of high quality, containing notable amounts of lysine and tryptophan. And baobab leaves contain very high levels of provitamin A, which means they could potentially prevent millions of children from going blind.

Celosia

Celosia leaves certainly contribute their share of nutrients, including calcium, phosphorus, iron, and vitamins, as well as not a little protein. Among people in the know, these dark-green leaves are especially valued for promoting physical stamina. Likely, they can play a part in reducing chronic malnutrition but so far there is no solid experience upon which to make a judgment.

Cowpea

Dried cowpea seed consists of protein (up to 24 percent) of good nutritional quality. The bean is nearly 2/3 complex carbohydrate, with some oil (up to as much as two percent), and minerals and nutrients of lesser stature. On top of that cowpea is palatable and relatively free of the kind of metabolites that suppress soybean's value in combating malnutrition. For all these reasons, this grain legume could have a fine future in more effectively balancing the diets of Africans by the millions.

Dika

Dika, too, offers good possibilities for lowering scandalous levels of chronic malnutrition. The kernel meal is high in oil and protein (including six of eight essential amino acids), and would make an exceptional nutritional tool in West and Central Africa where marasmus (the malnutrition caused by a lack of food energy) and kwashiorkor (the malnutrition caused by a lack of protein) are major baby killers. In addition, the fruit has more vitamin C than pineapple or orange and also has vitamin A in quantity. Collectively, these features make a strong case for more testing, more research, and horticultural development that might lead to many more purposeful dika plantings.

Eggplant (Garden Egg)

Although far from being nutritional powerhouses, these colorful egg-like fruits provide protein, vitamins, and minerals. By the standards of the modern Western world they are a dieter's dream: low in sodium, low in calories, high in dietary fiber, and a good source of potassium. For Africa, however, they probably lack the nutritional punch to knock out the malnutrition that threatens the lives of children.

Egusi

Wherever protein-calorie malnutrition remains chronic, egusi seed could provide an exceptional boost for public healthcare. More than half its weight is edible oil. Another 30 percent is a protein of high nutritional quality. The seed also contains important amounts of minerals and vitamins, especially thiamin and niacin. This is a nutritional combination of potent portent, considering that the crop can thrive where malnutrition among babies is rampant and infant formula is rare. It doesn't take much of any food that is half oil and almost a third protein to provide the calories and amino acids that stressed, sick, and fast-developing little bodies need each day. Egusi could thus be a vital tool against marasmus, kwashiorkor, and other nutritional debilitations.

Enset

On the face of it, enset flour is little more than pure starch. The crop is therefore more like a staple than a vegetable. Yet strangely, people in the enset zone of Ethiopia are renowned for superior nutritional status, perhaps because enset so effectively fulfills their quest for simple carbohydrates.

Lablab

With a crude-protein content of 20-28 percent, lablab seeds are worth considering in malnutrition prevention programs. In addition, the amino acids are moderately well balanced, with an especially high lysine content, which means that they help balance out diets that are over-heavy on the staples. The seeds are also a good source of energy. However, as with soybean, they contain antinutritional factors. The leaves, too, are rich in protein, as well as iron. Likely, this crop can play a big part in improving nutrition, but careful investigations are needed before proceeding on any mass scale.

Locust Bean

Locust beans make a concentrated food with a nice complement of protein, fat, sugar, starch, and fiber, not to mention vitamins and minerals. Lysine makes up about 7 percent of the protein, a level similar to that in whole egg, one of the gold standards of proteinaceous foods. The fat is of the unsaturated kind, the major fatty acid being linoleic—a nutritionally useful ingredient often deficient in the diets of the poor. The smelly fermented locust-seed product, dawadawa, is possibly more nutritious still, but the young who overwhelmingly make up the malnourished may not find it as appealing as everyone else does.

Long Bean

This vegetable is sometimes called poor-man's meat in Asia because it produces so prolifically and makes a filling meal. Long-bean pods, eaten like green beans, provide fairs amounts of provitamin A and vitamin C, and the leaves contain 25 percent protein of a high nutritional quality. Already well known in some places outside Africa, long bean seems like a ready tool for bolstering Africa's nutritional well-being.

Marama

On its face, marama is astoundingly promising for lifting nutritional levels in the dry zones. Its seeds rival soybean in both protein content and protein quality, and they far surpass soybean in edible oil content. On top of that, the tuber portion of the plant contains a remarkable 9 percent protein. Marama, however, is a wild plant of the southern African deserts and may prove

impossible to produce in quantity either there or elsewhere. At this time, the most appropriate actions involve cautious horticultural research and nutritional testing. This is a putative crop that first needs a foundation on which to build.

Moringa

In a few parts of Africa, various moringa products are already promoted as food additives. The pod provides *all* the essential amino acids; vitamins A, B, and C; and a wealth of minerals. Its high levels of iron and calcium make it particularly valuable for women young or old. The leaves are remarkable for methionine and cystine, vitamins A and C, calcium, and iron. In the Philippines, where moringa is exceptionally popular, these leaves are commonly boiled and fed to babies. They reportedly also increase lactation in mothers. Any foodstuff with such nutritional qualities could prove a potent means to fortify a malnourished continent, both directly and through mother's milk.

Native Potatoes

Native potatoes occur where a shortage of suitable vegetable crops now results in endemic malnutrition. They produce large amounts of good food from a small amount of ground. The tubers contain around twice the protein found in potatoes, and a meal can contribute most of a adult's daily requirement. A standard serving also provides a large percentage of the daily requirement of calcium and vitamin A, as well as more than the daily complement of iron. For a root crop, the content of essential amino acids and food-energy are notably high as well.

Okra

Okra provides three food products: pods, leaves, and seeds. All have dietary value. Half a cup of the cooked pods, for instance, provides nearly 10 percent of the recommended levels of vitamin B6 and folic acid, not to mention fair amounts of vitamins A and C. The leaves contain protein, calcium, iron, and vitamins A and C. The seeds are potentially a good source of an especially nutritious protein, rich in tryptophan and having adequate levels of the nutritionally vital sulfur-containing amino acids. Okra protein thus complements and fulfills that of cereal grains and legumes, not to mention of root crops.

Shea

Even though it is not a major portion of any meal, this solid vegetable fat has an importance to the inhabitants of the semiarid zone along the Sahara's southern edge that is difficult to overstate. It enhances the taste, texture, and

digestibility of the major regional dishes. This is not a vegetable like the others we describe, but for millions living in this harsh location, where food is difficult to produce and life hard to sustain, shea butter is a part of everyday existence. For the struggle against marasmus, this would seem a natural ally.

Yambean

African yambean is a classic in that it could benefit millions of the malnourished, but no one has yet championed its greater use. The seeds are about one-quarter protein, and the protein has essential-amino-acid levels likely to make it the soybean's nutritional equal. The tubers are nutritious too. Those swollen root tissues amount to 10 to 20 percent raw protein, which is of high nutritional quality. For children, especially, yambean may be valuable. Nibbling on the tasty raw tubers will provide a quality protein of a kind they cannot easily get elsewhere.

BOOSTING FOOD SECURITY

When considering the "facts of life" it is commonly forgotten that a primary one is the need to eat every day. Unfortunately, plants seldom provide their edible bounty on such a convenient schedule. This means that people who find their own food must withstand periods in which nothing can be gleaned from soil or shelves. In addition, for much of Africa the possibility of multi-year drought is a pervasive fear and a sometime purveyor of famine.

Sadly, those living in poverty have little margin for error: crop- and climate fluctuations or periodic natural disasters or human conflict quickly create conditions for catastrophe. And it is not realistic to expect that relief efforts can always succeed. Not surprisingly, though, there are ways indigenous vegetables can help fill even some of the longer gaps in the dietary continuum, both in normal and abnormal times.

Of special significance, here, is the fact that the native vegetables' adaptive qualities were selected by Africans under precisely the variable conditions and climatic vulnerabilities of that continent.

Below is a summary of the merits, *specifically in terms of food security*, of each of this book's 18 highlighted vegetables.

Amaranth

These plants already secure the food supply for millions. They are easy to produce and grow so fast that the first harvest can sometimes be gathered just three weeks after planting. Subsequently, several successive harvests can be made, and this aptitude for both jack-rabbit starts and for feats of endurance not only eases the farmer's burden in filling the family stomachs, it creates huge yields in the kind of small spaces relegated to the destitute and disenfranchised.

Bambara Bean

Due to its dependable production, bambara bean has the potential to improve food security in many rural areas. Indeed, it promises to become a stable, low-cost, and profitable food crop for Africa's small-scale farmers living where the rains are not to be trusted. Resilient and reliable, it commonly yields food from sites too hot and too dry for peanuts, maize, or even sorghum. It might truly prove an ideal insulator against starvation wherever rainfall is unreliable.

Baobab

Among vegetables, a food class renowned for short seasons and transitory availability, baobab is a leafy vegetable that keeps on producing throughout

the rainy season—often half the year. In addition, any surplus harvest can be dried. In desiccated form, the leaves keep well even under the pest and climatic pressures of rural Africa. Clearly, this is a food-security treasure.

Celosia

A supremely self-reliant and uncomplicated resource, celosia propagates easily, requires little care, and often reseeds itself like a weed. Its Malawian name means “eaten by lazy ones,” a recognition that not only is it easy to produce but it cooks quickly and efficiently. As a back-up security support for subsistence farming this lowly herb seems to offer true value.

Cowpea

One of the more remarkable and precious things about this species is that certain of its cultivars mature with as little as 300 mm of rainfall. This makes it the grain legume of choice for the Sahelian zone and the contiguous savannas, both of which are surprisingly populated, erratically dry, and vulnerable to mass outbreaks of malnutrition and misery. Cowpea seeds provide quality protein and other essential nutrients that complement the otherwise unbalanced diets the poorest sectors are forced to stomach.

Dika

The fruits have traditionally been collected from wild trees in the forests, so not much has been reported about their likely ultimate contribution to food security. Nonetheless, harvesters gather dika nuts by the thousands of tons each year, and those dried kernels are especially stored for the hungry season.

Eggplant (Garden Egg)

This is a resource that is easy to raise, relatively free of disease and pests, and capable of providing a steady supply of both food and income. The plants are known for a capacity to furnish terrific amounts of food from a tiny space. Also, the fruits have a storage life up to three months. Having firm skins, they also transport well. Furthermore, this African eggplant can be dried and stored for later use, notably in emergencies such as when the growing season is finished and nothing fresh is available.

Egusi

Noteworthy is the fact that egusi seeds can be stored for long periods without particular trouble from pestilence or degradation. This is one oilseed that can supply food year-round. And it is a quality food: the oil making up the seed’s largest nutritional component is polyunsaturated.

Enset

Enset's importance for poor-people's food security seems self-evident. Interviews with farmers suggest that Ethiopian peoples who depend on the plant NEVER suffer famine. Indeed, a family with just a small plot of enset supposedly will have food forever. This long-lived species represents natural food security, always available for general use, or for exclusive use in rare times when all other eatables fall short.

Lablab

This is not an exceptional food-security crop, but a well-established lablab plant's root system often penetrates into water sources more than 2 m deep, permitting luxurious growth to persist long after the rains have ended and the surface soil is parched. Because of its extended production season, the crop continues providing food, fodder, and soil protection long after other herbaceous species have dried and died.

Locust Bean

This is one of the best species for securing a supply of food when nature has other plans. Although locust beans are a part of the daily diet across a zone often devastated by drought, this tree also turns into a lifesaver during famine times. Its seeds contain protein, fat, sugar, starch, vitamins, and minerals, and are about as balanced and concentrated a food as could be devised. Add that they mature in the dry season, the traditional "hungry time," and their value as emergency food becomes plain. Even when drought has seared the landscape, this deep-rooted tree continues producing its foodstuffs, as if on its own schedule.

Long Bean

Long bean plants are succulent and therefore probably not the greatest security food, but they not only thrive in hot humid climates, they produce food very quickly. Indeed, the leaves can be harvested within three weeks of planting, and some types produce harvestable pods inside two months. The main varieties continue producing for months on end, thus giving rise to an extended harvest that keeps providing fresh food over long periods.

Marama

This protein and energy-rich species nourishes people in southern regions where rain is so slight and erratic that some years almost none whatever falls. It lives through such conditions, not to mention blistering summers, apparently with ease. In addition, it survives low winter temperatures, especially the freezing nights of the Kalahari. But as a continental food

source it hardly seems promising, owing to its lack of horticultural development and apparent narrow geographic range.

Moringa

A rugged, resilient tree species, moringa tends to produce well in marginal growing conditions and is a reliable source of greens in seasons and locations where few other vegetables produce much of anything. In West Africa the leaves appear at the end of the dry season, a time when other sources of leafy green vegetables have mostly died. All this adds up to a food-security gem.

Native Potatoes

These tubers, which are overwhelmingly employed as subsistence food, also make a good food-security insurance policy. They can, for example, be dried and set aside for the hungry times. These clonal crops are easy to handle and propagate. Taken all round, then, these ancient resources could prove good tools not only for reducing malnutrition and hunger, but for tiding African families through the times when other food is unavailable.

Okra

Although not normally grown under stressful conditions, the plant shows considerable tolerance to drought and heat, and should perform more reliably than most plant resources in Africa's savanna regions, where food supplies are currently often undependable.

Shea

Traditionally, this large and treasured tree, not unlike oak in general appearance, provided the primary edible vegetable fat to peoples inhabiting a vast tract of wooded grassland that is vulnerable to some of the worst droughts of the arable world. Nutritionally speaking, it is noteworthy for providing buttery kernels capable of providing a steady source of dietary energy year-round.

Yambean

With built-in adaptability to a wide range of climates and soils, African yambean is a reliable performer. It grows easily and is well suited to the hot wet tropics, an environment unfriendly to so many crops that people there suffer from a lack of healthful agronomic options.

FOSTERING RURAL DEVELOPMENT

Beyond their fundamental subsistence use, vegetables make good cash crops. They command relatively high prices and can be produced efficiently on a small scale. This makes them excellent resources for relieving rural poverty. Like fruits, they provide farmers an easy entry into the world of commerce and into at least the prospect of prosperity. Indeed, anyone with access to land can grow vegetables.

For many rural Africans, these plants and their products provide opportunities for economic gain. Many species are already grown at home and sold in local markets; children also collect them to sell within their village. Nevertheless, supplies now reaching the cities are generally considered to fall far short of the natural demand.

Mostly, vegetables are produced by women, peddled by women, and prepared and served by women. They therefore offer a convenient lever for lifting female existence to a higher plane. This is of broader importance than may be apparent: Improve the lives of women, and you improve the lives of babies born and unborn. In a related vein, vegetables offer good opportunities for gender-oriented innovation and female-led entrepreneurial enterprises.

Below is a summary of the merits, *specifically in terms of improving rural development*, of each of the 18 vegetables highlighted in this book.

Amaranth

In the lives of the rural poor this low-cost crop is notably important as a source of income. Many desperate farm families grow more amaranth for sale than for their own subsistence. Women are the prime producers. The crop is mostly grown, harvested, and marketed close to home, and it forms a crucial part of both the rural economy and the female existence. Thus if science can boost output or reduce production costs it will disproportionately benefit not only the group most at risk but also the one most likely to support society.

Bambara Bean

This crop has outstanding commercial possibilities. Beyond the normal farm and village sales, commercial food processing is likely to open up buoyant new bambara-bean markets. In this regard, it is notable that the canned product seems to have high marketing potential in urban areas. Across Africa there is room for bambara-bean-processing enterprises, which will create new outlets for farmers and boost income opportunities for rural areas. There’s even potential for world exports.

Baobab

Africa's most emblematic tree is also a likely vehicle for poverty prevention. Traditionally, baobab has not been deliberately cultivated, merely encouraged and protected. However, farmers in West Africa have recently begun producing it in an organized way for vegetable markets in the city. This is succeeding because where baobab trees aren't available for the picking, the leaves necessary for the evening meal must be purchased. For city-dwellers finding that can become a never-ending struggle: Making baobab-leaf sauce can at times cost the equivalent of a day's work. On the other hand, sales continue brisk and country-women derive important income from selling the leaves.

Celosia

Celosia seems a promising green for commercial cultivation in the hot humid tropics, especially during the rainy season, when other crops succumb to molds, mildews, and like maladies. It can be very high yielding and its young leaves have a good taste and a good nutritional value. Celosia is already southern Nigeria's most important leaf vegetable and is raised in myriad home gardens and farm plots both for the family and the local marketplace.

Cowpea

Beyond its value to the malnourished, this is a high-potential cash crop. At present it is the second most important grain legume across the African continent; only peanut—a scion of South America—occupies more African farmland. Nigeria, the biggest producer, grows several million tons a year, yet its potential across a broader swath of Africa is scarcely considered.

Dika

Through dika, millions of farmers already earn a critical income. They sell the fruit for juice, jam, jellies, and the fresh market. In addition they sell the oil to factories making margarine, soap, or pharmaceuticals. The greatest profit center of all, however, is in the defatted kernel meal. This shelf-stable soup ingredient even has export potential. Indeed, entrepreneurial West Africans living in the United States already hawk molded ogbono cubes, mostly over the internet.

Eggplant (Garden Egg)

Throughout Africa, local garden eggs provide a continuing source of income for farmers. In rural districts from Senegal to Mozambique women are commonly seen hefting baskets of them on their heads to sell in nearby villages or townships. Yet these vegetables have untapped commercial

promise and could become the cornerstone of localized rural economic development drives. There is also perhaps potential for exporting African eggfruits to Europe and North America and thereby earning hard currency.

Egusi

Egusi seed is in high demand in tropical markets, especially those in urban areas. Almost all the food sellers in Benin, Cameroon, Ghana, Nigeria, Togo, and the other nearby nations display it for sale. Egusi is also peddled over the Internet to aficionados around the world. From greater production and greater profitability women would be special beneficiaries. They are the main growers and, due to the relatively high cash income they receive, egusi is already a sort of female treasure.

Enset

Enset's importance extends far beyond food; every part is useful for something. Farmers in Ethiopia's southern highlands declare that, "enset is our food, our clothes, our beds, our houses, our cattle feed, and our plates." In other words, this is a crop of life; like coconut it provides a basis for subsistence survival. Although much is sold in Addis Ababa, whether the crop can be harnessed for commercial purposes more widely in Africa is far from certain.

Lablab

The forms of lablab that have been developed as green vegetables are promising profit-makers, producing huge yields of pods (up to 7.5 tons per hectare) that look and taste good, and doing it quite quickly (4 months). In addition, the dry seeds are becoming commercially important in Australia, where it is claimed that they are suitable even for export (mainly as livestock feed), like some sort of southern-hemisphere soybean counterpart.

Locust Bean

Across West Africa locust seed is a major item of commerce, as is its famed fermented paste, dawadawa. These together constitute an important economic activity for women. Production of the pungent dawadawa is a traditional family craft and, although most is produced for home use, it also commonly ends up sold in local markets.

Long Bean

This productive legume yields a lot of food in a very small space. On worn-out soils it is said to out-produce peanuts. A true legume, it is largely independent of fertilizer....enriching soil by trapping atmospheric nitrogen in bacteria-filled nodules on its roots. It not only fits into African farming, it

also fits into African cuisine, especially into the vegetable-laden sauces and relishes. These tasty, universally admired treats therefore hold out the prospect of a good income for those who choose to grow long bean for profit.

Marama

As of now, this is too far from being a commercial crop to promise purely economic benefits.

Moringa

Potentially there is profit to be made from what at present is a quintessential subsistence resource. First, moringa is a fast-growing, high-yielding oilseed. Second, the trunk is gaining importance as a raw material for papermaking. And third, pods and leaves could be produced for the fresh market or for processing. Adding to its rural-development benefits is the discovery that the seeds can help purify water. There are indications, too, that moringa-seed extracts make useful treatments against skin complaints. Moringa is also valuable as feed for livestock.

Native Potatoes

Although native potato is not a cash crop in the normal sense, part of the harvest is commonly put up for sale in the villages. Collectively, African women derive income thereby. It is notable that the crop occurs in areas of low agricultural potential across the continent's most needy regions. In addition, prepared food products seem quite possible. Native potato therefore holds the potential to provide more income to those who produce, collect, and process the tubers, most of them female.

Okra

Okra could have an unexpectedly important future as an industrial crop. There seems to be little difficulty in producing the plant on any particular scale. In the United States, for example, some is already produced in quantities big enough for the pods to be canned, frozen, or brined for supermarkets coast to coast. In addition, okra could, at least in principle, have a future producing things that are unexpected from a vegetable crop, including construction materials, handicrafts, forage, and fuel.

Shea

Shea is often a principal economic resource underpinning the lives of those inhabiting vast areas where little else saleable can be found or farmed. According to estimates, the tree provides more than half of all women's income in the rural Sahel. Foreign exchange is also earned: both seed-

kernels and the butter are shipped to Europe and Japan, where they are processed into baking fat, margarine, cocoa-butter substitutes, and various highly touted beauty aids. Some of these are appearing in North America too.

Yambean

Possibly the African yambean will make a valuable cash crop across regions that desperately need a farm-based fulcrum for leveraging rural development upwards. The highly efficient way in which it absorbs nitrogen makes it an especially attractive tool for helping those who suffer due to worn out soil. The tuber yield is generally high and can undoubtedly be raised—possibly dramatically—merely by preliminary research attention. But as of now there is not much documented experience this grossly neglected resource, so the future cannot be judged with any clarity.

SUSTAINABLE LANDCARE

After decades of focusing on fewer and fewer farmed foods, agriculture is once again promoting a diversified "product line." At the same time, numerous farming techniques are being discovered—or rediscovered—that yield bounteous crops reliably while leaving the land better off than before the crop was grown. Many of these technologies require little capital investment, making them ideal for the cash-poor countryside. Peering forward from today's limited perspectives on diversity and sustainability, it seems likely African vegetables provide opportunities for more sustainable land use, in large measure because of the relative gentleness with which they treat the land. In addition, they provide ecosystem services: pollen and nectar for bees, for instance, or effectively swath the soil. In addition, their increased use acts like an in-situ conservation program that, at least in some measure, helps preserve Africa's ancient heritage of food plant genes. This is important because the diversity in these crops is diminishing and essentially nothing is being done to conserve them in a comprehensive manner.

Below is a summary of the merits, *specifically in terms of sustainable landcare*, of each of the 18 vegetables this book highlights.

Amaranth

Amaranths demonstrate exceptional vitality in many types of sites. Most are pioneer species, whose niche in nature is the quick colonization of disturbed land. They use the C4 photosynthetic mechanism, common in arid-land species, which enables them to survive not only hot weather but dry weather as well. Given some ingenuity, it seems they could be turned to good account for quickly protecting naked land until it can be re-clothed with a longer lasting cover.

Bambara Bean

Bambara bean epitomizes the idealists' ideal of a "sustainable crop." Every plot is a mixture of genetic diversity and no plant is fertilized or sprayed. In addition, the species' nitrogen-fixing capacity helps boost soil fertility, naturally. The crop can even be used as a soil conditioner. And beyond all that, it thrives in laterite, the ancient, reddish acidic soil substrate that is toxic to many plants and is an underlying curse of tropical agriculture. Programs aiming to achieve sustainable farming in Africa could find bambara bean a good foundation around which to base their programs.

Baobab

Extending the use of baobab leaf to regions beyond West Africa offers possibilities for enhancing both the crop and the environment, not to

mention nutrition and rural prosperity. Already often likened to "Africa's soul," this is a tree that can tap into the heart of many of the continent's most basic needs: humanitarian, economic, *and environmental*.

Celosia

Humidity and heavy rainfall fail to limit growth, so celosia is commonly cultivated during the wet season when other crops collapse due to weather or wanton maladies. Because of its tolerance to conditions both wet and dry, and because it is usually unaffected by pests, diseases, or soil type, it is among the most promising greens for unforgiving or fickle growing conditions. The plants spring up with surprising vigor from tiny seed. They have special promise for cultivation next to millions of huts and hovels, whose occupants can then pluck off some leaves each day and drop them into the soup pot. This is about as gentle an agriculture as is possible.

Cowpea

One of the best landcare food crops, cowpea has deep roots that help stabilize the soil as well as dense foliage that shades and covers the surface and preserves moisture. Both these below-ground and above-ground traits are of special importance in the dry zones, where moisture is at a premium, soil is fragile, and wind a dirt-scouring demon. Like most other legumes, cowpea fixes atmospheric nitrogen, thus lifting the nitrogen content in the soil around it. It is often intercropped with sorghum, millet, or maize, as much to foster their good health as to furnish its own beans.

Dika

Dika thrives in places such as the evergreen forests of Central Africa, and its special adaptation to heat and humidity raises the possibility of improved forms becoming employed in the form of an eco-friendly crop for dense, moist, heavily shaded conditions. Also, in southeast Nigeria, dika has been extensively planted to control soil erosion. In the future, it might even help reduce the pressures to damage the ecosystem whose future worries so many today: the African rainforest. People with dika trees will have few pressures to seek new land to cultivate.

Eggplant (Garden Egg)

This very adaptable crop can be grown in widely different climates. The plants are fast maturing and produce several harvests of fruits, so they yield both quick results and extended ones. This notably benefits soil conservation activities, especially when eggplant is used to cover bare soil in the spaces between the farm's main crops. They tend to tolerate shade and so can be fitted in around various taller plants, such as bananas, cassava, and trees.

They are suited to various infertile and difficult soils, and are likely candidates for wringing food and income from numerous kinds of "agricultural wastelands." All this makes garden eggs good for the ground.

Egusi

Egusi is easy to grow. Indeed, it survives on barren sites, not to mention some of the driest and most climatically challenged locales. Further, it blankets the soil and helps protect the surface from damaging rain and wind. Most of all, though, this vigorous annual suppresses weeds. The plantings may need a month or so of tending, but after that they typically remain weed free.

Enset

Surprisingly, farmers often do little to maintain or improve their enset plots, other than add manure. Although they incorporated exceptional quantities of animal waste, it is still fair to say that the plant provides a long-term sustainable food supply with minimal inputs. It is said that many enset fields have been in continuous production for decades, if not centuries, and yet they remain productive, stable, and unfailing. If any food crops can match that record we've not heard of them.

Lablab

Beyond all its uses for food and fodder, the plant can be used advantageously to provide organic matter and fix soil nitrogen, thereby boosting subsequent crop yields in a cheap and environmentally friendly manner. It is possible that lablab could become an essential part of certain sustainable farming systems. Managers of coconut, rubber, and oil-palm plantations know from long experience that it is one of the most valuable, trouble-free, and trustworthy of all leguminous herbs for suppressing weeds and rejuvenating worn-out soils. To them the food is a trivial matter by contrast with the environmental advantage.

Locust Bean

It is noteworthy that the locust tree tolerates a wide range of alluvial, sandy, and lateritic soils. It also resists pests and diseases, survives fires, and thrives in full sun and fearsome tropical heat. Moreover, its deep roots make it almost independent of equable rainfall. All this would seem to make locust an ideal candidate for mass planting in appropriate parts of Africa, notably the once-forested savannas. The trees also promise to make many now sun-drenched streets and highways into shady food waysides. All in all, more locust beans—whether planted for provisions or protection—add up to more hope for a better continent.

Long Bean

Although nothing is reported about long bean *per se*, other cowpea forms fix nitrogen efficiently and make useful living mulches for restoring barren land. Long bean should do the same. Indeed, it has been called a nearly perfect match for Africa's soil, Africa's weather, and Africa's people. The seeds of select strains also cook fast, an important consideration wherever fuelwood is scarce and expensive, as it is in that vast parched crescent of concern between Senegal and Mozambique.

Marama

In principle at least marama should prove ideal in the vulnerable drought-prone sandy zone of southern Africa. But not enough is known about this crop to suggest large-scale "environmental" plantings.

Moringa

This raggedy species looks like a forester's nightmare but its ability to thrive in wastelands and provide rapid tree cover could make it the choice for many reforestation projects. Likely, too, it is a good nurse crop for slower-growing species that eventually dominate the site. In addition, moringa is an excellent candidate for fast-track beautification of streets, slums, and squatter settlements. The presence of the living tree, though far from spectacular, improves the scene as well as the surroundings—providing shade and shelter from the elements.

Native Potatoes

While much remains to be learned about the native potatoes themselves, a recent report declares that: "root crops will be many things to many people by 2020." Driving the authors to this deduction is the adaptation of root crops to marginal environments, their vital role in promoting food security at the household level, and their flexibility in mixed farming systems. There's no reason to doubt that such conclusions also apply to these little-known root crops and that the African landscape will benefit thereby.

Okra

By and large, okra seems an eco-friendly crop. Though not a legume, it is not destructive to the soil. Quite the opposite: At the end of the harvest season, the foliage and stems can weigh 27 tons per hectare. With fuel costs rising worldwide, okra biomass seems likely to become more notably useful than even now, especially as more tropical forests are destroyed.

Shea

Shea (and locust) commonly provide the only tree cover across a vast area that is vulnerable to desertification. A self-reliant perennial species providing food in the dry, drought-seared savanna would seem the ultimate in sustainable agriculture. Making the most of the difficult climate and the most of the largely worn-out soil, the trees need little care and may live for centuries. The time-honored farm/park landscape covering major portions of the Sahel is said to be a perfect example of large-scale agroforestry at its best.

Yambean

African yambean could well prove to have a superb soil-repairing capacity. Already, there is preliminary evidence that it could be excellent for crop rotations, for ground cover, and for binding soil. The plant thus seems a fine candidate for sustainable development purposes. This is, in other words, a food source that supports itself while helping both the soils beneath and the species surrounding and succeeding it.

* * *

The brief synopses above have focused on the promise of these African vegetables. The chapters that follow, from which these summaries were pulled, offer additional detail on both the promise and challenges faced by those choosing to work with these plants.

DESCRIPTIONS AND ASSESSMENTS OF INDIVIDUAL SPECIES

1

AMARANTH

To the world of science, vegetable amaranths verge on the invisible. As far as international statistics are concerned, this crop doesn't exist. Books highlighting world food plants, even those dealing specifically with vegetables, largely ignore it or accord only the briefest mention. Not surprisingly, then, researchers engaged in improving global food supplies pay little heed. Indeed, most may have never heard of a vegetable amaranth.

Yet if this leaf crop seems invisible, it is only because it is hidden in plain sight. At least fifty tropical countries grow vegetable amaranths, and in quantities that are far from small. Throughout the humid lowlands of Africa and Asia, for instance, these are arguably the most widely eaten boiled greens. During the production season, amaranth leaves provide some African societies with as much as 25 percent of their daily protein. In parts of West Africa the tender young seedlings are pulled up by the roots and sold in town markets by the thousands of tons annually. Other parts of the continent also rely on them to a similar degree. A definitive review of southern Africa's native foods, for example, clearly lays out their status: "Of all the wild edible plants eaten in southern Africa, few if any are as well known and widely used as amaranths."[1]

Amaranths are a poor people's resource, and the plants are often dismissed as "lowly" and ignored as if, like poverty itself, they should be avoided at all costs. As a United States Department of Agriculture bulletin points out, few species of vegetables are so looked down upon. Several languages include the demeaning phrase "not worth an amaranth." Indeed, the plants are sometimes regarded as being fit only for pigs ("pigweed" is the common name for one despised American species).

At first sight, this scorn seems almost universal. *Amaranthus* is one of the few genera whose species were domesticated in both the Old and New World.[2] It has provided very ancient potherbs (boiled greens) not only to Africa but to Asia and the Americas as well. Nowadays the various species from the different tropical regions are pretty much scrambled up genetically, so that the origins of any given amaranth plant remain (at least for the

[1] Fox, F.W. and M.E. Norwood Young. 1982. *Food from the Veld: Edible Wild Plants of Southern Africa*. Delta Books, (Pty) Ltd., Johannesburg.
[2] Many of the more than fifty *Amaranthus* species in both tropical and temperate regions are eaten, but only a dozen or so can be considered domesticated.

Vegetable amaranths are probably the most widely eaten boiled greens throughout Africa's humid lowlands. They secure the food supply for millions. The leaves and stems make excellent boiled vegetables with soft texture, mild flavor, and no trace of bitterness. (Jim Rakocy)

moment) fuzzy.[3] This seems to be especially the case in Africa.

Amaranth leaves and stems make boiled vegetables with soft texture, mild flavor, and no trace of bitterness. In taste tests at the U.S. Department of Agriculture in Beltsville, Maryland, most of the 60 participants said that cooked amaranth leaves tasted at least as good as spinach. Some likened the taste to that of artichoke.

Given the food-production experts' lack of interest, one might imagine these plants to be difficult to grow and unappealing to the growers. But such is not the case. Amaranths produce seeds aplenty and their seedlings emerge so rapidly and sprout with such vigor that the first crop of leaves is sometimes harvested within three weeks of planting. Furthermore, new generations of leaves keep materializing, so that many harvests can be made before replanting becomes necessary. This aptitude for extended production not only eases the farmer's burden, it leads to huge yields: one test produced 10 tons of edible greens per hectare in a 30-40 day harvest period.

Given their general lack of recognition, one might imagine these lowly

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[3] Generally the wild species are considered to have hybridized frequently with the cultivated and thus produced a series of intermediate types.

plants to lack nutritional power. Actually, they have high food value. The leaves have an exceptional protein quality, (25 percent for *Amaranthus cruentus*) reportedly containing more lysine (about 0.8 percent for *A. cruentus*)] than quality-protein maize (high-lysine corn) and more methionine than soybean meal. In addition, vitamins A and C occur in good quantities. Minerals such as calcium and iron are also present in abundance.

Given their lack of recognition one might imagine these lowly plants to possess such strict climatic and soil requirements that they grow well only in limited locations. Once more, however, the truth is quite the reverse. Amaranths demonstrate exceptional vitality in many types of sites. Most are pioneer species, whose niche in nature is the quick colonization of disturbed land. They therefore produce a huge number of fast germinating seeds and this may be why a classically minded botanist named them amaranth, an Ancient Greek word meaning "life everlasting."[4] The plants use the C4 photosynthetic mechanism, common in arid-land species, which enables them to thrive not only in hot weather but in dry weather as well.

Although in most of the lowland tropics the upper crust may hold vegetable amaranths in low esteem, in Caribbean nations the whole society honors these plants. The humble leaves are important ingredients in Caribbean cooking, especially in the famous regional favorite known as callaloo,[5] which is normally a gumbo-like stew or a spinach-like vegetable dish that often features the texture of Africa's okra (see Chapter 16). Callaloo is so central to the diet that it has become almost synonymous with the Caribbean image. The word has entered everyday talk as a word denoting the unique blending of food, language, music, and peoples constituting Creole culture. The name callaloo is appended to restaurants, magazines, shows, songs, bands, books, and more. It is an appellation bestowed with pride.

In China and Southeast Asia, a region renowned for quality vegetables, one amaranth—Chinese spinach, *Amaranthus tricolor*—ranks among the very best. Farmers in Hong Kong, for example, grow at least six types: pointed leaved, round leaved, red leaved, white leaved, green leaved, and horse's teeth. Those in Taiwan grow a type called tiger leaf, which has green leaves with a red stripe down the center.[6] They're not only very pretty, they're very tasty.

The fact that vegetable amaranths aren't honored like this everywhere is a shame. These classic poor-people's plants provide a perfect botanical tool

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[4] The family was so named by Antoine Laurent de Jussieu (1748-1836), a remarkable botanist who named 100 plant families. The power of his insight can be judged from the fact that 76 of the names, including Amaranthaceae, remain in use to this day.

[5] Variously spelled callaloo, calaloo, callalou, callalou, callalu, and calalu. Various Caribbean countries make callaloo from both amaranth *and* other plant leaves, especially Asia's dasheen (taro); in Jamaica, however, amaranth and callaloo are synonymous.

[6] Herklots, G.A.C. 1972. *Vegetables in South-East Asia*. Hafner Press. New York

for helping the most nutritionally challenged strata of society. Taken all round, they represent a sort of do-it-yourself kit to good nutrition and lend themselves ideally to subsistence conditions. With them, little horticultural experience is needed before the benefits of better nutrition can be enjoyed. Although insect pests and diseases can be problematic, few if any tropical vegetables are easier to grow. In favorable locations amaranths produce food almost without attention.

Seen in overall perspective, these fighters offer frontline armaments in the battle to feed properly a malnourished world. They yield protein and other nutrients efficiently. They afford abundant provitamin A (beta-carotene), a nutrient vital to the millions of malnourished children now at risk of blindness. And they do it quickly.

In summary, amaranths are an important market vegetable for many farmers, but their main benefits are humanitarian ones. Without these humble plants, the hidden hunger of malnutrition would be much worse. With them in greater use, it can be greatly lessened.

PROSPECTS

Although vegetable amaranths have yet to catch the attention of most researchers and scientific establishments, few crops can match them for effectiveness in nutritional interventions. In places such as Africa they offer an easy entree intervention because they are even now consumed by, admired by, and sought by the rural peoples for whom food insecurity is a daily peril.

Within Africa

Humid Areas Excellent. *Amaranthus* species are of course already used widely as potherbs in the humid lowland tropics. Over the years, growers have selected types with leaves and stems of high palatability. The mild taste, high yields, high nutritive value, and ability to withstand hot climates make them popular. In flavor, food value, and "farmability," they are the best of all tropical potherbs.

Dry Areas Modest. Given their C4 photosynthesis, amaranths thrive, or at least survive, under droughty conditions. However, for good production under dry conditions supplemental water must be applied. The plants tend to

grow very rapidly and they have high leaf areas (and thus high evaporation losses), so to attain top production and maximum palatability they require

ample water.

Upland Areas Good. With a fast-growing leaf crop like this, altitude is little barrier. Amaranth was a mainstay of ancient South American civilizations, produced at about the highest elevations known to agriculture.

Beyond Africa

Nothing restricts these plants to Africa. Prospects elsewhere are excellent. Indeed, the leafy amaranths have reached their greatest development in Asia. Furthermore, many species from this genus are cultivated in Mexico as well as in Central and South America. And in the Caribbean, of course, they are a mainstay of the traditional cuisine.

USES

This is a multiple-duty crop.

Leaves Leaves, young stems, and young inflorescences are eaten as potherbs. Although much of the pigment leaches out on boiling, the leaves retain a pleasant green color. They soften up readily, requiring only a few minutes cooking, which helps avoid excessive nutrient loss. Unlike some African potherbs, they need no added soda or potash to make them palatable. The leaf is also tossed into soups and stews. The boiled leaves may be rubbed through a fine sieve and served as a puree.

Salad Plant Very young leaves may be used in a mixed salad. Sometimes the whole plant is pulled up after it has developed eight or twelve leaves, and used directly in salads. The leaves, their petioles (stalks), and the plant's young growing tips are sometimes used in fresh green salads also. The flowers, however, are inedible.

Seeds Several species, including *Amaranthus cruentus*, *A. hypochondriacus*, and *A. caudatus* are grown for their grain-like seeds. Although small, these seeds occur in prodigious quantities. In carbohydrate content they equal cereals such as wheat, but have more protein (over 17 percent in some strains) and more oil. When heated, amaranth grains burst and take on a toasted flavor not unlike that of popcorn, which is very appealing. However, in many areas, they are more often parched and milled into flour. Bread made this way has a delicate, nutty flavor and is used notably by gluten-sensitive individuals. Pancake-like chapatis made from

amaranth are a staple in the Himalayan foothills.

Stems While most leaf amaranths are about 60 cm high, some varieties reach 2 m. It is reported that Singaporeans peel the stem of one of these tall forms and eat it separately. The report notes that to the taste buds they are "excellent."[7] In Bangladesh, special cultivars (of *Amaranthus cruentus*) are grown for the stems (food).

Decoration Amaranths are well known ornamentals, used worldwide to brighten window boxes, gardens, parks, and public buildings. The flowers can be strikingly attractive with bright colors and showy form.[8] Even without flowers some types are decorative. Certain amaranths have red striations in their green leaves due to the presence of anthocyanins. These can be very attractive and (like the tiger leaf variety in Taiwan) edible too.

Feeds Vegetable amaranth can also be used in feedlots for cattle or other intensively reared animals. In the early 1990s a husband-and-wife scientific team carried seed from Pennsylvania back home to China. The seed was from grain amaranths, and they expected to foster a new cereal-like food crop for their country. Instead, Chinese farmers adopted it for forage. Subsequently, it has become very popular in every one of the 29 provinces and is now grown by an estimated one million farmers who keep a pig or two around the house.

Other Uses It is reported that in South Africa's Queenstown district amaranth greens are eaten only by women, who believe—perhaps with good reason—that the young tops promote the flow of milk. The attractive flowers make *Amaranthus cruentus* a suitable species for honey production.

NUTRITION

The nutritional quality of amaranth greens is not dissimilar from that of better-known leafy vegetables. However, they tend to accumulate more minerals, notably iron and calcium, and amaranth greens rank at the top when measured against other potherbs.

Their exceptional protein quality makes them useful supplements to cereals and root foods. Protein levels in the leaves are reported around 30

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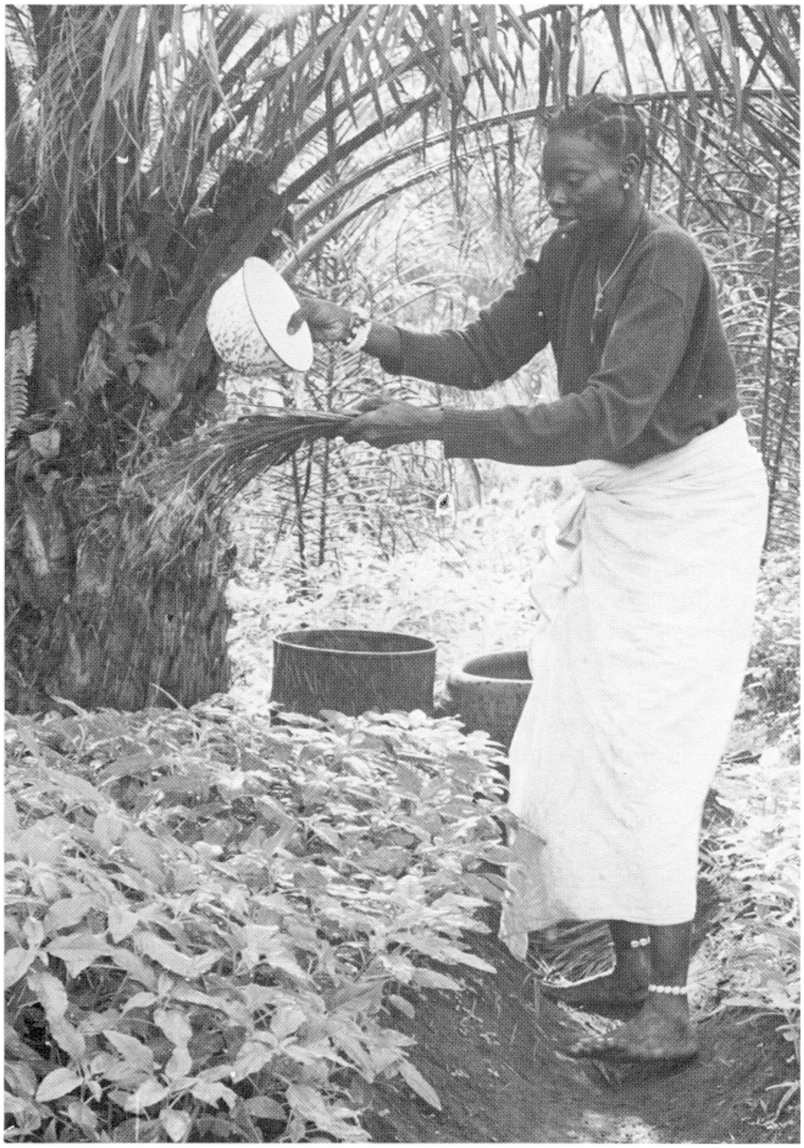
[7] Herklots, 1972

[8] These ornamental types go by many flowery names, including love-lies-bleeding, prince's feather, red amaranth, blood amaranth, cockscomb, Hell's curse, and Jacob's coat.

percent.[9] Protein quality is high as well. The amino acid composition of *Amaranthus hybridus* leaf protein, for example, shows a chemical score of 71, comparable to spinach. Elevated levels of the nutritionally critical amino acid lysine have been found in the leaves of 13 amaranth species. This makes it leaf protein a very good supplement to cereal grain. In India, weaning foods have been fortified with amaranth leaf flour.

[9] These are dry-weight basis. The figures were 27 percent for *Amaranthus blitum*, 28 percent for *A. hybridus*, 30 percent for *A. caudatus*, and 33 percent for *A. tricolor*.



This shade-loving crop can be fitted in around various taller plants, such as bananas, cassava, and trees. Amaranth greens are mostly grown, harvested, and marketed close to home, and women are the prime producers. Indeed, in several dozen nations this popular plant forms a crucial part of both rural economy and female existence. Here in Benin, a villager uses palm leaves and a bowl of water to sprinkle the amaranth bed in her home garden. (G.J.H. Grubben)

Vegetable amaranths are important sources of vitamin C as well as abundant precursors for producing vitamin A, whose lack blinds thousands of children each year.[10]

The minerals of importance in amaranth leaves are calcium and iron. Some doubt exists as to their availability in the human body, yet the contribution to people deficient in iron seems to be considerable.

HORTICULTURE

Amaranth is an important market vegetable grown by professional vegetable farmers. It is estimated that in Indonesia 20,000 hectares are planted per year. Amaranths are also cultivated in home gardens for family use, with any small surplus being carried to the village market in the form of tiny bundles of plants tied in bush fiber. The plants are sown virtually year-round in the tropics, and multiple cropping is possible due to its short life cycle (about 8 weeks).

Propagation is generally by direct seeding. Normally, the small black seed is broadcast very thinly (a seeding rate of 2 g per m^2 has been suggested) on prepared beds. The tiny seeds are covered with a little soil (a depth of a little less than a centimeter being recommended). The seed may be sown in nursery beds and subsequently transplanted to the field as seedlings.

Given sufficient rainfall and warm weather, growth is rapid. Within a month, indeed often within three weeks, the seedlings are big enough for eating or for transplanting. Typically, the plots are thinned at this stage, leaving the strongest and best plants. The seedlings weeded out are usually quickly washed and dumped into the cooking pot, roots and all.

Various expedients are employed to prolong leaf production. Repeated pruning is one. Another is pinching out the plant's growing tip, which 1) forces branching and the production of new and tender lateral growth and 2) suppresses any tendency toward early flowering. Keeping the plants thoroughly watered is a third method for extending the season. This lessens any tendency toward drought stress, which can trigger early flowering.

No matter what methods are used, eventually every plant proceeds to flower. Their value for food then plummets, and the plants are removed or let go for seed.

Fertilization with nitrogen stimulates vegetative growth and boosts yield substantially. To generate the greatest amount of the tenderest leaves, the

[10] According to the USDA, a 100g bowl of cooked leaves can provide more than half the daily adult needs for vitamin A; see www.ars.usda.gov/nutrientdata for additional information on thousands of foods, including a few in this report.

plants should be well watered and the soil fertilized, preferably with manure, compost, or nitrogenous fertilizer, during the period of active growth.

HARVESTING AND HANDLING

The plants grow rapidly and may be harvested when they reach a height of 30 to 60 cm. Although the whole plant can be uprooted, most are cut back, which both produces a harvest of leaves and encourages lateral growth. As many as 10 weekly harvests have been reported.

If the entire plant is harvested, a garden plot of 10 m^2 can yield 20 to 25 kg of tasty vegetable. If the leaves and lateral shoots are picked individually several times over, the same small plot can average 30 to 60 kg total yield. On a per-hectare basis, vegetable amaranth yields are generally in the range of 4 to 14 tons green weight. However, harvests as high as 40 tons per hectare have been reported.[11]

It is traditional in West Africa to soak the plant in water before toting it to market. This gives the leaves a fresh look. Typically the leaves are arranged in bunches, spread on a raffia tray, and hawked in market stalls or in the street. Since they lose moisture rapidly, the leaves are regularly sprinkled with water whilst awaiting a buyer.

LIMITATIONS

The grain's small size makes this crop tricky to plant. To ensure good germination the seeds must be close to the soil surface, which means that a hard rain or even a flush of irrigation water can wash them all away. The whole planting is thus often protected with a thin covering of grass mulch, which is removed after germination. This vulnerability is also a reason why some farmers sow the seeds in nursery beds, where the plants can be crammed together and protected fairly easily. Then, when the plants are beyond this danger, the farmer transplants them into the production plot. This is a particularly useful method to use during the rainy season.

The tiny seeds—about the size of sand grains—are also difficult to spread evenly across the soil surface. To get around this, the seeds are mixed with sand. Sowing the combination helps space out the plants and attains uniform dispersal.

Slugs and snails often severely damage young plantings, but the worst enemies of amaranth leaves are leaf-chewing insects. Larvae of moths and butterflies, as well as leafhoppers, leaf miners, grasshoppers, and leaf-

[11] Yields vary with the cultivar. In a test in the Virgin Islands, for example, the yield of fresh edible leaf was almost 1.2 kg per m^2 for one cultivar ('Callaloo') and merely 240 g per m^2 for another ('Greenleaf'). In this trial, the number of days from planting to first harvest ranged from 40 to 47 days. Palada, M.C. and S.M.A. Crossman. 1999. Evaluation of tropical leaf vegetables in the Virgin Islands. Pp. 388–393 in J. Janick, ed., *Perspectives on New Crops and New Uses*. ASHS Press, Alexandria, Virginia.

feeding beetles may very quickly decimate a planting. This is a problem without a universal solution at present. One useful practice is to cover the bed with a screen fine enough to keep the creatures out. This is of course cumbersome and tedious, but can be effective in the tiny plots in which vegetable amaranths are typically grown. Commericially, some amaranths are grown in screen or net houses that keep out all insects.

Diseases are also a problem. The plants are susceptible to viruses as well as fungal maladies, especially when they are young and the weather is damp. Generally speaking, vegetable amaranths grow poorly during long periods of cloudy, wet weather. During monsoon, for example, diseases such as damping-off (from *Pythium* and *Rhizoctonia*) can become serious. To reduce such diseases, the seedbeds must be well drained and located in sunny sites. Manuring can reduce or eliminate some of the attacks by strengthening the plants. Various fungicides have been successful also.

The C4 form of photosynthesis lends *Amaranthus* species a special competitive edge, to which is attributed their wide geographic dispersal and compatibility with diverse conditions. This is also why many amaranth species have turned into weeds. They are not, however, monsters of the weed world, just commonplace companions that pop up in the strangest spots, and in some of which they're unwanted.

Although the fresh leaves of some vegetable cultivars can glow with something akin to red fire, when they are boiled the brilliant pigment dissolves in the hot water. The leaves come out emerald green, but the cooking water turns dark and far from pretty.

That cooking water should be tossed out because it contains more than just pigment. All leafy vegetables accumulate antinutritional factors, including oxalic acid, betacyanins, cyanogenic compounds, saponins, sesquiterpenes, polyphenols, and alkaloids such as betaine. Amaranth is no exception, and all these compounds, which interfere with our ability to utilize nutrients, are reported in various *Amaranthus* species. All, or perhaps most, of the harmful compounds are leached out in that cooking water.

The young and very tender leaves have the least amounts of these undesirable materials, which is why the plants should be picked early and often. It is also why they should be well watered, fertilized, and generally kept lush and vigorous and freshly formed.

NEXT STEPS

As noted, vegetable amaranth is in a sense invisible to the authorities. Now is the time to open everyone's mind to the crop's promise. The primary monograph on it was published decades ago.[12] That and other books highlighting such tropical vegetables need to be available, widely

[12] Grubben, G.J.H. 1976. *Cultivation of Amaranth as a Tropical Leaf Vegetable*. Department of Agriculture, Royal Tropical Institutes, Amsterdam.

disseminated, and revised, helping researchers engaged in improving global food supplies to pay these plants heed. Indeed, a worldwide collegial partnership to foster greater use of vegetable amaranths is worth mounting.

Horticultural Development Selection and crossbreeding is one area that could bring rapid advances. *Amaranthus* species demonstrate high levels of variability in leaf size, leaf shape, branching, bolting pattern, growth and regrowth ability, and color. Indeed, the vast wide geographical spread of the genus has produced many landraces, and in their present undeveloped state amaranths offer more genetic diversity than do many much better understood crops. The huge gene pool in widely separated areas can be tapped for the future development of the crop. This is an excellent genus as well as an excellent time in history for plant explorers and local plant lovers to get engaged.

One of the least known and least developed species is *Amaranthus thunberghii*, a semi-wild species native to southern Africa. This seems to have exciting potentials and clearly deserves increased attention. It grows very fast and is resistant to water stress. It is also tolerant to many insect pests such as aphids, fall armyworm etc. *A. thunberghii* has a more prostrate growth habit than its relatives, which may or may not be a benefit. It has been classified as an aphid-trap plant, which opens up intriguing possibilities for research endeavors.

Although vegetable amaranths have been neglected, this dereliction is, as we've said, not universal. Asian growers have been making selections by decades. Named varieties suitable for widespread culture are available from seed companies in Hong Kong, Taiwan, the United States, and elsewhere; many can be located on the internet. These "elite" forms are probably the most technologically advanced and most thoroughly developed forms.

Regarding vegetable amaranths, much crop improvement has been done, but more could be accomplished by studies of:

- Pest and disease resistance;
- Nutrient uptake and nutrient content at different stages of growth;
- The yields from clipping versus successive planting;
- Regrowth after harvest ("ratooning") and the best height at which to clip the plant and the best intervals between clippings;
- Seed production and farmer-selection techniques;
- Leaf-to-stem ratio;
- Delayed flowering;
- Planting and cultural practices for efficient use of land, water, and fertilizer; and
- Crop rotation to avoid soil-borne diseases.

Also needing study is the forage use of leafy amaranth. The recent

Chinese experience is especially illustrative of the potentials and the possible means for feeding pigs with "pigweed."

Food Technology Deserving of research and testing are:

- Food quality, including tenderness and storage methods to prolong the life of the harvested produce;
- Leaf color and antinutritional factors. It seems likely that the bright red and purple-leafed types are the least desirable as foods;
- Accumulation of antinutrition factors in response to type and quantity of fertilizers and soil;
- The variation in flavor among varieties;
- Effect on nutrient retention by processing, such as boiling, steaming, or drying (for later availability during the dry season);
- Provitamin A and iron bioavailability;
- Product development;
- Toxicological studies; and
- Nutritional studies, such as supplementation effects.

Actually, some research in these areas has already been conducted and efforts are needed to make the results more widely known and better used.

Vitamin A On the face of it, amaranth leaves could be an important remedy for vitamin-A deficiency, one of the world's horrors that is subject to increasingly intense outside interventions. Many or most of the programs could incorporate vegetable amaranth. Benefits could accrue not only to Africa but to Indonesia (a country notable for this blindness-inducing affliction) and other parts of Asia.

Leaf-Protein Isolates A future promise of vegetable amaranths is the development of leaf-protein concentrates.[13] Compared with most other species, amaranth leaf protein is highly extractable. In one trial, amaranth had the highest level of extractable leaf protein among 24 plant species studied. During the extraction of protein, most other nutrients are extracted as well: for example, provitamin A, polyunsaturated lipids (linoleic acid), and iron. Heating or treating the extract with acid precipitates the nutrients as a leaf-protein concentrate. In the process, most harmful compounds are eliminated, as they remain in the soluble phase. The green cheese-like coagulum is washed with water slightly acidified with dilute acetic acid (vinegar) to reduce further amounts of possible antinutritive factors. The resulting leaf-nutrient concentrate is especially useful for young children and

[13] The pioneering work by Rolf Carlsson (University of Kalmar, Sweden) on the use of amaranth leaf-protein is especially to be noted here.

other persons with particularly high protein, vitamin A, and iron needs. The fibrous pulp left after extracting the amaranth greens is a suitable feed for animals. The protein quality of the amaranth leaf-nutrient concentrate (based amino acid composition, digestibility, and nutritional effectiveness) is excellent. It is, however, species dependent, probably because of the presence of secondary substances.

Special Interest Projects It has been reported that amaranth is highly suitable for incorporation into crop rotations. It is usually unaffected by common soil diseases such as nematodes, fungal, and bacterial wilt.

Recent reports claim that amaranth benefits from intercropping with species such as celosia and/or jute (*Corchorus*). Further confirmation is in order because this could be an exceptionally important finding. Rotations between these rather similar potherbs could be advantageous to nutrition and dietary variety as well as yield.

SPECIES INFORMATION

Botanical Name *Amaranthus* spp.

Family Amaranthaceae

Common Names

Afrikaans: hanekam, kalkoenslurp, misbredie, varkbossie
Congo: bitekuteku (*Amaranthus viridis*, Kinshasa Province)
English: African, Indian, or Chinese spinach, tampala, bledo, pigweed, bush greens, green leaf,
French: calalou, callalou
Spanish: bledo (Central America)
Fulani: boroboro
Ghana: madze, efan, muotsu, swie
Sierra Leone: grins (Creole), hondi (Mende)
Hausa: alayyafu
Temne: ka-bonthin
Philippines: kulitis (Ilongo), uray (Tagalog)
Indonesia: bayam itik, bayam menir (Java), bayam kotok (Sumatra)
Thailand: pak-kom
Nigeria: efo, tete, inene
Jamaica: callaloo
Tswana: imbuya, thepe
Venda: vowa
Xhosa: umfino, umtyuthu, unomdlomboyi
Zulu: imbuya, isheke
Malawi: bonongwe
China: hiyu, hon-toi-moi, yin choy, hin choy, een choy, tsai

India: Ranga sak, ramdana, rajeera, lal sak, lal sag
Malaysia: bayam puteh, bayarn merah
Caribbean: callaloo, calaloo, etc.

Description

Amaranthus species are herbaceous, short-lived annuals. The plants are upright and sparsely branched. The stems are erect, often thick and fleshy, and sometimes grooved. Dwarf forms, about 60 cm high, are best for the small garden. The leaves are normally alternate and are relatively small (5-10 cm long), but the lines grown as vegetables mostly have leaves longer than normal. The leaves show much variability in shape, color (principally green or red, but some varieties are purplish with the pigment betalain). The flowers are small, regular, and unisexual and are borne in abundance in terminal or axillary spikes. The seeds are small, shiny, and black or brown.

Distribution

Within Africa Several species of amaranth are in cultivation but *Amaranthus cruentus* (*A. hybridus*), *A. blitum* and *A. dubius* are the most widely grown in Africa and are particularly important in West Africa.[14] Hybrids between species and varieties exist, some of which have been designated as species or subspecies.

Beyond Africa Several species exist depending on the region in the tropics. For example, *Amaranthus tricolor* is mostly found in East Asia, China, and India (where amaranths are especially ancient and diverse) while *A. caudatus* is common (as a cereal) in the Andean nations of South America and throughout the Himalayas, and *A. dubius* (as a vegetable) in the Caribbean, India and China. *A. hybridus* is grown for grain or vegetable production in the southwestern United States, China, India, Indonesia, Malaysia, Mexico, Thailand, Philippines, Nepal, the Caribbean, and most likely many other places.

Horticultural Varieties

Unlike the crops in other chapters, this one occurs as separate species, including the following:

Amaranthus cruentus L. This grain type has a long stem and bears a large inflorescence. A very deep red, dark-seeded form of the species, sometimes known as blood amaranth, is often sold as an ornamental in commercial seed

[14] The Asian species, *Amaranthus tricolor* (*A. oleraceus*, *A. gangeticus*) , an import from India, is sometimes seen, but rarely.

packets. Like corn, sweet potatoes, peanuts, and other American crops, *Amaranthus cruentus* was evidently introduced to Africa by Europeans. But then it passed quickly from group to gruop outrunning European exploration of the interior, so that Livingstone and others found it already under cultivation when they arrived. The white-seeded form is used as a cereal. The black-seeded version is the one used as a vegetable, and it has probably been used that way in Africa since the 16th or 17th centuries.

Amaranthus dubius Mart. ex Thell. This weedy species is a green vegetable of West Africa and the Caribbean, and is found in Java and other parts of Indonesia as a home garden crop. One of its best varieties, the cultivar 'Klaroen,' is particularly popular in Suriname and has been introduced in Benin and Nigeria. This fast growing, high yielding plant has distinctive dark-green, broad, ridged leaves and is considered very palatable. It is the only known tetraploid (2n=64) in the genus.

Amaranthus hybridus L.[15] One of the world's most common leafy vegetables, this weedy herb originated in tropical America, but is now spread throughout the tropics and is a frequent component of kitchen gardens. It also grows wild on moist ground, in waste places, or along roadsides. The plant is fast growing, requires little cultivation, is resistant to moisture stress and produces a good yield of grain in sorghum-like heads. The size and color vary greatly. Red-stemmed varieties are usually planted as ornamentals; green varieties are the ones employed as vegetables.

Amaranthus blitum L. This widely distributed species (also known as *A. lividus*) is well adapted to temperate climates and has a number of weedy forms that come with either red or green leaves. It promises to allow the development of highly palatable crossbred vegetable amaranths. In Madhya Pradesh, India, the edible forms, known as norpa, are especially liked for their tender stems. This species is widely eaten in Greece under the name vleeta. It is also grown in Taiwan, where it is known as horsetooth amaranth. A widespread weed of waste and cultivated ground, it is commonly eaten in many parts of Africa. The leaves are soft and the cooked product is sweet tasting and much liked.

Amaranthus tricolor L. Varieties of this species are native to a large area from India to the Pacific islands and as far north as China. It is probably the best-developed vegetable amaranth: the plants are succulent, low growing, and compact, with growth habits much like spinach. They are produced as a hot-season leafy vegetable in arid regions when few other leafy greens are

[15] The exact relation between this species and *Amaranthus cruentus* is in dispute. The two may be wild and cultivated forms of the same species or they may be species apart.

available. In India, a large number of cultivars are available, especially in Andhra Pradesh, Karnataka, Tamil Nadu, and Kerala. Some ornamentals with very beautiful foliage also belong to this species. There are many cultivars in Southeast Asia classified according to leaf color and shape.

Environmental Requirements

Vegetable amaranths need a long warm growing season, and are suited only to the warm-temperate and hotter zones of the earth. If grown in cooler climates they tend to be tough and poor in quality.

Rainfall The crop thrives in areas receiving 3,000 mm of annual rainfall. As it is mostly grown in small plots beside the house, it is frequently watered by hand. Without irrigation it needs an average of at least 8 mm per day of rainfall during its whole season.

Altitude Areas with elevations below 800m are said to be most suitable for cultivation, but the crop can be grown in higher areas. *Amaranthus cruentus*, for example, thrives in altitudes up to 2,000 m.

Low Temperature All species are very sensitive to cold weather. Plant growth ceases altogether at about 8°C.

High Temperature Most species are tolerant of high temperatures and thrive within a temperature range of 22-40°C. The plants establish best when soil temperatures exceed 15°C. Optimum germination temperature varies between 16°C and 35°C.

Soil Although most amaranths tolerate a wide range of substrates, a light, sandy, well-drained, and fertile loam is desirable. Soils with a high organic content and with adequate nutrient reserves produce the best yields. Optimum pH range is 5.5-7.5 but some cultivars tolerate more alkaline conditions.

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BAMBARA BEAN

In recent centuries the once-obscure peanut has expanded so dramatically as to become one of the world's top crops. Of particular importance to Africa, the peanut (there mostly known as groundnut) contributes substantial nutrition to roughly three-dozen nations encompassing two vast belts, one stretching from Senegal to the Central African Republic and the other from Sudan to South Africa. Indeed, considered in continental perspective, peanut is among the largest African food providers—probably coming right after maize, cassava, and sorghum.

What is surprising is that peanut is a Brazilian native that reached Africa's shores only 400 years ago. And what is even more surprising is that Africa possesses its own counterpart. This local version is similar in virtually every aspect—botanical, agronomic, nutritional, and culinary. Yet while the exotic crop soars to ever-greater heights its stay-at-home cousin languishes almost unknown to agricultural science, food science, economic development, and the world at large.

This African species (*Vigna subterranea*) is a low-growing legume, not unlike its famous relative in appearance. Often called bambara groundnut, it is conventionally classified a bean, but its seeds are actually dug from the ground like peanuts. To outsiders, only the shape seems unusual: the pods are larger and rounder than peanut shells and the seeds inside are shaped more like peas than peanuts. Those spherical legumes are, however, exceptionally tasty and nutritious. They are also attractive—appearing in varying colors and patterns, characterized by pretty local names such as *dove eyes*, *nightjar*, and *butterfly*.

Like peanut, these native ground beans make a versatile food. Most are boiled in their shells and are offered for sale, ready cooked, on roadsides and in markets. Others are pounded into flour and used in making porridge. Some are boiled with maize meal and used in a relish. A few are also roasted or fried. The flour from the roasted version is especially appetizing and is blended into many traditional dishes.

Although overlooked by the world at large, this is an important resource. Burkina Faso provides a picture of the crop in microcosm. All regions of the

Bambara bean is a low-cost, dependable farm resource that grows in harsh environments where many other crops fail. Production is primarily at subsistence level, and only the surplus is sold. For Africa, the crop offers various benefits, being an ideal subsistence crop, a good rotation crop, a good backstop for hungry times, and a promising commercial resource. (Klaus Fleissner)

country grow bambara bean, producing around 20,000 tons in total.[1] Cultivation is exclusively using traditional methods and traditional landraces. Some farmers intersperse the plant among other crops but most grow it in mini-monoculture. Much of the harvest is consumed by the farm family, for whom it is a major source of protein and a lifesaver during the hungry season—the period before the new crops are ready to harvest and the old have been eaten. Beyond this fundamental subsistence use, however, bambara is also a cash crop. Popular with the general public, the fresh beans sell for a premium. There's never a problem peddling any surplus, and the local sales can constitute the grower's overall annual cash income.

The question is why does such a valued resource remain largely unknown to agricultural science, food science, humanitarian programs, and economic development policies?

Clearly, the neglect is no reflection of the user's views. Despite peanut's spectacular surge, its African counterpart remains a consumer favorite. Indeed, even without the help of science sales are actually edging upward. Today, probably more than 100 million Africans routinely rely on this age-

[1] This makes it Burkina Faso's third largest grain legume, after peanut (160,000 tons) and cowpea (74,000 tons). Kiwallo, L. 1991. Inventaire des maladies cryptogamiques du voandzou (*Vigna subterranea* (L.) Verdc.) au Burkina Faso. *Mémoire de fin d'études en agronomie*. Institut du Développement Rural, Université de Ouagadougou, Burkina Faso.

old resource for at least part of their sustenance during each year. Overall production is around 330,000 tons, about half of which is grown in West Africa; the rest in eastern and southern Africa.[2]

Clearly, too, the intellectual inattention is not due to any agronomic inferiority. Bambara bean is a dependable food producer, tolerating harsh conditions and growing reliably in challenging locales, including some where other species fail. It is also among the easier legumes to grow: burying its fruits in the soil, it keeps them safe from the myriad flying insects that can devastate or destroy cowpea, common bean, soybean, and other legumes that heedlessly wave their tastiest parts in the air.

Nor is the disregard due to site restrictions. Other than requiring open sunlight and light, loose soil within which to bury its beans, bambara tolerates widely dissimilar substrates, including infertile ones. Indeed, some observers swear it "prefers worn-out soils."[3] Furthermore, this leguminous species fixes nitrogen from the air, thereby insulating itself from Africa's all-too-common paucity of soil-nitrogen. And beyond all that, the plant thrives in laterite, the reddish acidic soil that is toxic to many crops and is the curse of tropical agriculture.[4]

Doubts about nutritional performance are not the cause of the neglect either. Ripe or immature, raw or roasted, the seeds pack a load of nutrients. On average, they contain about 60 percent carbohydrate, 20 percent protein, 6 percent oil, and a range of vitamins and minerals. This makes them more like a bean than a peanut. A true quality-protein food, they provide more methionine than other grain legumes, let alone the standard staple cereals.

Despite all these benefits, bambara bean has never been accorded a research program commensurate with its importance or potential. Indeed, it has probably received less than a ten-thousandth the technical support the peanut enjoys worldwide. The neglect is only partly because the plant is stigmatized as a "poor person's crop". Rather, it seems largely due to lack of familiarity by those setting the research agenda, especially research donors and agricultural scientists outside Africa.[5]

Now is the time to open minds and award this native resource a greater chance to catch up with peanut. Given technical support, this resource

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[2] Linnemann, A.R. 1994. Photothermal regulation of phenological development and growth in bambara groundnut (*Vigna subterranea* (L.) Verdc.). PhD Thesis, Wageningen Agricultural University, The Netherlands, and Kiwallo, op. cit.

[3] Their observation probably reflects the fact that stress typically stimulates plants to set more seed.

[4] Information from J. Ehlers.

[5] Such institutional inertia can be energized by initiatives such as "BamNet," the International Bambara Groundnut Network founded in Zimbabwe in 1995. Composed mainly of researchers, mostly in Africa, BamNet hopes to improve productivity, marketing, and consumption by sharing experiences. Coordination is done largely through the Internet. Such home-grown initiatives—often driven by just a few committed individuals—make a world of difference in securing the future for these plants.

certainly can contribute vastly more than it does today. Indeed, the plant has the potential to cut to the heart of Africa's great humanitarian problems. Consider the following:

Rural development In the lives of the rural poor this low-cost crop is especially important. Many desperate farm families grow it for their own subsistence and also for their annual income. Thus any boost in output or reduction in production costs will disproportionately benefit the group most at risk. Also, commercial food processing is likely to open up buoyant new market outlets. In this regard, it is notable that the canned product seems to have high marketing potential, especially in urban areas. A Zimbabwean company already cans bambara bean, and reports that (except for "baked beans") it sells as well as any other canned bean—nearly 50,000 cans a year, with sales increasing month after month. Across Africa there is room for many such enterprises, and they will create major markets for farmers and boost income opportunities for rural areas.

Hunger For most of the drier regions bambara bean could contribute to a solid foundation diet. Resilient and reliable, it commonly yields food from sites too hot and too dry for peanuts, maize, or even sorghum. And it produces a food of exceptional nutritional quality, so a little of it goes a long way toward maintaining health.

Malnutrition Compared with peanut, bambara may have a lot less oil and a little less protein, but more carbohydrate and the overall combination nicely balances the food groups. People can live on bambara bean alone, a doubtful proposition even with other legumes. A rare example of a complete food, it could prove a tool for attacking Africa's chronic malnutrition.

Gender Inequality This bean is mostly produced by women, sold by women, and cooked and served by women. It therefore offers a convenient lever for lifting women up to a better existence. Improve this resource and you improve the lives of millions of mothers, not to mention babies born and unborn. In a related vein, bambara bean offers good opportunities for gender-oriented innovation and commercial development. In the Bida region in central Nigeria, for instance, women make pancakes from the flour and reportedly enjoy a good living selling them. Also in Mali women sell salted bambara nuts, a premium product similar to macadamia nuts and suitable for urban areas and possibly for export as well.

Food Security For much of Africa unpredictable drought is the biggest fear, and this crop might prove an ideal insulator against this periodic shock. Wherever rainfall is unreliable it tends to shine. Bambaras—the people for whom it is named—live in parched, blisteringly hot districts along the

Most seeds pods are picked while still soft and immature; the seeds are eaten fresh or roasted. With a calorific value equal to a quality cereal, this pulse is suitable for use as a staple. As with chickpea and lentil, this legume sustains life. (Werner Schenkel)

Sahara's southern fringe, and their namesake plant lives up to its etymological heritage.

Sustainable Agriculture Bambara bean epitomizes the current ideal of a "sustainable crop." Every plot is a mixture of genetic diversity and no plant is fertilized or sprayed. In addition, the species' nitrogen-fixing capacity helps boost soil fertility, naturally. It can even be used as a soil conditioner. Programs aiming at achieving sustainable farming in Africa could find no better foundation upon which to build their efforts.

Trade Deficits Countries along the southern Sahara have long shipped bambara beans to markets on the Gulf of Guinea coast. Niger is the principal exporter, followed by Chad, Burkina Faso, Mali, and Senegal. Those happen to be among the nations most needful of foreign exchange, and enhancing this particular trade could be part of the answer. Reportedly, the coastal areas have a still unmet demand.[6] A similar situation apparently exists in

[6] This is according to a study issued by the International Trade Centre in Geneva, among others.

southern Africa as well. Although Zimbabwe has exported thousands of tons of the dried beans to its neighbors, there is believed to be openings for more.

In sum, bambara bean promises sweeping benefits to the people most in need and hardest to reach through conventional development programs. And despite the almost total scientific neglect, nothing fundamental is stopping this crop from moving on to greater heights.

Of course, technical difficulties deserve attention (as they do with corn and soybean and all crops). These are treated later in the chapter, but it is worth highlighting one example: low yield. Average farm production is now around 400 kg per hectare, yet under improved conditions the crop produces over 4,000 kg per hectare. Farmers today, therefore, achieve merely a tenth of what they could. Clearly, the opportunities for improvement are huge. And the results would be staggering indeed if, in rural areas of hard-pressed countries such as Burkina Faso, ten times more bambara beans could be produced. The effects would in fact be revolutionary.

PROSPECTS

Empirical evidence and preliminary investigations suggest that with attention, bambara could rise to prominence within just the next 20 years. From today's perspective, that might seem farfetched, but peanut's stellar performance shows how quickly a newly appreciated resource can ascend.[7]

Within Africa

Due to its relative resistance to diseases and pests, bambara bean has the potential to improve food security in many rural areas as well as become a stable, low-cost and profitable food crop for Africa's small-scale farmers. Given the support of good science, conducive government policy, bold investment by food processors, and dedicated local initiative, it could soon be reducing malnutrition and raising both economic levels and human well being.

Humid areas Good. Although details remain sketchy, the plant is capable of growing in rainy areas. However, dampness brings out fungal diseases and means that the plant needs careful handling. Also, the harvest must be made promptly—before the tops have signaled their readiness by turning

[7] Researchers for the FAO, taking bambara as an example of an "underutilized crop," used weather, soil, and other data to model its potential for growing across Africa and the globe. Their predictions show it widely adaptable to much of the area of peanut and beyond, especially the Mediterranean rim. Azam-Ali, S., J. Aguilar-Manjarrez, and M. Bannayan-Avval. 2001. *A Global Mapping System for Bambara Groundnut Production.* FAO Agricultural Information Management Series No. 1. FAO, Rome; available online via www.fao.org/documents/.

yellow. And special provisions are needed to dry the seeds and store them safely.

Dry Areas Excellent. Bambara bean is one of Africa's most drought-tolerant native legume food crops.

Upland Areas Good. The crop does well in the highlands of Zambia and Zimbabwe. At Gwebi in Zimbabwe, for example, yields of 4,000 kg per hectare have been realized.[8]

Beyond Africa

Bambara bean is cultivated in Brazil (under the name *mandubi d'Angola*) as well as in at least two parts of Asia: West Java and southern Thailand. In principle other tropical locations could grow it too. It is said that the crop could produce in the Middle East. FAO studies claim that both Syria and Greece are suitable. Small-scale cultivation trials have been successful in United States, notably in Florida, but no one has yet tried moving it into general production.

USES

Like most legumes bambara bean is used in a variety of ways.

Home Uses As mentioned, in many African countries the pods are boiled and the seeds consumed as snacks. This seems to be the most widespread use. However, in East Africa, the beans are roasted, pulverized, and used as a base for soups that can be either bland or made zesty with added chilies.

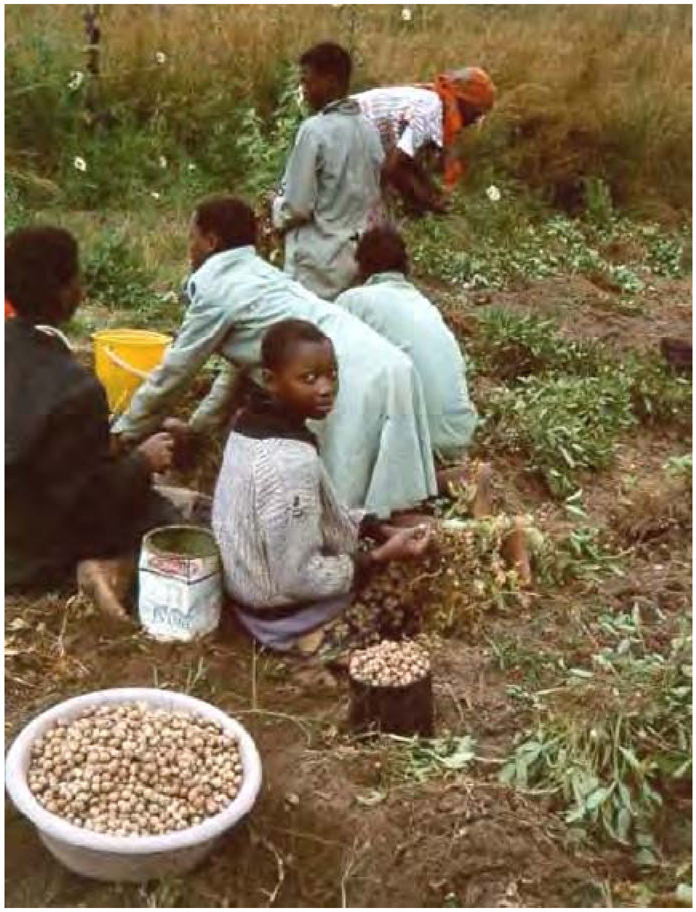
Processed Foods Any seeds that reach full maturity turn hard and indigestible, and require boiling and/or grinding into flour to become edible. Such flour is commonly used to thicken and flavor cereal products. In Zambia, it is also made into bread. In Zimbabwe, as we've said, bambara bean is canned.[9]

Another common practice is to crush the dried seeds into a paste. Various fried or steamed products made from this are very popular in Nigeria and neighboring nations. One, called *akara*,[10] is a form of bean fritter that is frequently sold on the street and is especially common at bus stations.

[8] This was at the research station, at about 1,500 m above sea level. Information from D. Greenberg.

[9] Zimbabwe was not the first. In Ghana, a government factory at Nsawam (just north of Accra) canned bambara groundnuts in gravy and for years sold well over 40,000 cans annually. Sadly, when privatized the company dropped this part of the business.

[10] Other names include *accra*, *akla*, *binch akara*, *kosai*, *koosé*, *kwasi*, or bean balls. It is also prepared at home for breakfast, snacks, or side dishes at dinner.



Manzini region, Swaziland. The family of Mrs. Fakudze (at back wearing headscarf) helps harvest the bambara crop. Like peanut, the plant forms pods and seeds underground. Unlike peanuts, the seeds are round, smooth, and very hard when dried. Among the most adaptable of all crops, it tolerates harsh conditions and yields food in droughty sites where peanuts, maize, or sorghum fail. (Karen Hampson)

Another, called *moin-moin*, is a sort of savory bean pudding. Yet a third, *okpa*, is a doughy paste that is wrapped in banana leaves and boiled. These age-old favorite "fast-foods" are mainly made with other beans, but those made from bambara are considered the best.

Oilseed With an oil content of only around 6 percent, bambara bean would seem to make for an unlikely oilseed, but reportedly some peoples in Congo pound the roasted nuts and separate the liquid for cooking.

Animal Feed Bambara beans have been fed to chicks with great success. The leaves, which are rich in protein and phosphorus, make useful livestock fodder. The haulm (stems, leaves, and other crop residues) is palatable, rich in nitrogen and phosphorus, and is also highly suitable for grazing animals.

Medicinal Use Among beans this one is said to have the highest concentration of soluble fiber, a non-nutrient famously occurring in oatbran and believed to reduce the incidence of heart disease and to help prevent colon cancer.[11] In addition, the crop has medicinal uses in many areas in Africa. In Botswana, for example, the black seeded landraces have the reputation of being a treatment for impotence.

Other Uses By contributing nitrogen to the soil the living plant is a good companion in crop rotations.

NUTRITION

Ripe or immature, the seed averages 63 percent carbohydrate, 19 percent protein, and 6.5 percent oil.[12] The protein, as formerly noted, contains more of the nutritionally essential amino acid methionine than that in other beans, making it more complete.

The seed has the reputation of being very filling. And no wonder: its nutritional energy (per 100g) has been measured at 367-414 calories, an amount greater than that of common pulses such as cowpea, lentil, and pigeon pea.[13]

Although formal infant-feeding studies are unreported, a trial has been conducted of "milks" prepared from bambara bean, cowpea, pigeon pea, and soybean.[14] Whereas all were declared acceptable, the scientists ranked bambara-milk first in flavor, nutritional value, and color. The mothers and (seemingly) their babies preferred it too.

HORTICULTURE

The plant comes in two basic shapes: a sprawling, ground-hugging type and a more upright, "bunched" or bush type that stands erect. The former is grown exclusively by smallholders as a subsistence crop; the latter is the one planted in larger-scale farming. Because there are no formal varieties, all

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[11] Information from D. Greenberg.

[12] The ranges of these ingredients are carbohydrate, 55-72 percent; protein, 17-25 percent; and oil, 5-8 percent.

[13] FAO. 1982. *Legumes in human nutrition*. FAO Food and Nutrition Paper No. 20. FAO, Rome.

[14] Brough, S.H., S.N. Azam-Ali, and A.J. Taylor. 1993. The potential of bambara groundnut (*Vigna subterranea*) in vegetable milk production and basic protein functionality systems. *Food Chem*. 47:277-283.

plantings involve mixtures of landraces selected during traditional production.

So far, there are no standard methods for handling the crop. Speaking generally, it is produced like peanut. Most farmers sow early in the rainy season, usually dropping two to four seeds into a hole about 5 cm deep, and covering them with soil. Planting density is normally low, especially when the planting is not organized in rows. The literature gives the optimal spacing as anything from 40x25 cm to 60x60 cm. Given the mixture of seeds emergence is necessarily variable, extending from 7 to 21 days.

The crop is most often sown in the family's main field (rather than its kitchen garden), frequently being tucked into the corner of the maize or sorghum plot. Some farmers use ridges or mounds. As with peanut, they "hill up" the plants.

Soil is the key to success: It must be loose and loamy enough for the pegs to penetrate. Those fragile flower stems emerge from the base of the pealike yellow blooms, elongating until they meet the soil below. Once they've pushed below the surface, the tips swell and the seeds begin forming. As the seeds mature below ground, the aboveground parts gradually lose their vivid-green vitality and turn yellow, a signal that the seeds are ripe for digging.

Given that fertilizer is uncommon in Africa, this crop's requirements are unrecorded. In West Java, the one place where farmer practice has been detailed, urea is sometimes sprinkled around the young plants. In southern Thailand, where soil fertility is quite low, any available fertilizer is applied as a side dressing along the rows at rates up to 150-300 kg per hectare.

HARVESTING AND HANDLING

Like peanut, bambara bean develops slowly. Depending on climate and cultivar it may take anything from 90 to 180 days to mature. Most of today's main types are ready to harvest in 130-150 days, or about 2 months after the pods first appeared.

In the dry zones, the timing of the harvest is less critical than with peanuts; bambara beans can be gathered early or late without serious loss. However, if they are to be used as snack, they must be harvested just before the leaves begin yellowing. And in humid areas prompt harvest becomes vital because seeds left in the warm damp soil can rot or germinate.

To harvest the crop, the whole plant is pulled up. With the bunched-type, most pods remain attached to the root crown. The per-hectare yield is generally 300-600 kg of dried seed. As we've said, much better production is possible: Six independent trials in several Central African countries recorded yields in excess of 2,000 kg of shelled seeds per hectare.[15] A 1969 report from Ukiriguru Experiment Station in Tanzania recorded yields up to

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[15] Johnson, D.T. 1968. The bambara groundnut: a review. *Rhodesia Agric. J.* 65:1-4.

2,600 kg per hectare. Various other documents refer to experimental yields in excess of 3,000 kg per hectare. And in West Java yields of 5,000-6,000 kg per hectare are recorded.

Freshly harvested pods are typically left in the sun several days, during which time they shrink, darken, and dry out. After threshing to separate the vegetable matter, the harvest is marketed either as pods or as seeds.

In storage, shelled bambara beans are susceptible to bruchid beetle. The pods, however, are extremely resistant. Farmers therefore keep their seeds for planting in the unshelled form.

LIMITATIONS

On the agronomic front, the lack of varieties with stable and predictable yield is the main concern. Formal attempts at breeding have so far been unsuccessful. Every planting therefore now employs landrace mixtures, and plants in a single field differ wildly in appearance, performance, and product.

A point that has only recently been recognized is that the crop—or at least some of its types—is photosensitive.[16] This could explain why some cultivars mature exceptionally late. Photosensitivity can be a two-edged sword. On the positive side, it can ensure that certain types mature at exactly the right time (usually the end of the rains) for a given location. On the negative side, it can restrict the seeds to that same location and to a single planting time each year.

The plant nodulates freely. Specific *Rhizobium* strains can boost its growth far above normal (with average strains), but as of now those select strains are poorly characterized and the farmers are not benefiting much from them.

Despite its general robustness, this plant can fall victim to fungal disease (notably fusarium wilt and leaf spot). Usually this occurs only when and where the conditions are unusually damp. On the other hand, viral diseases are widespread across many environments, especially where cowpea and other grain legumes are grown.[17] Also, even when hidden below ground the seeds are not entirely beyond danger: Rodents, crickets, and (in especially dry weather) termites can be problematic. In sandy soils nematode infestations can be bad.[18]

The pegs seldom penetrate far, which is why the farmers "hill" soil over them. Any that stay exposed to sunlight tend to turn green and to develop improperly.

The crop has potential for large-scale production, but under the rigors of

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[16] Linnemann, op.cit.
[17] Common are cowpea mottle virus and cowpea aphid-borne mosaic virus.
[18] In Botswana, for example, farmers who lack the land to rotate their crops are reporting heavy losses. Information from S.K. Karikari.

mechanical harvesting the current types tend to "shatter" (drop their pods). A related problem is the lack of a mechanical sheller.[19]

Although genetic diversity can be a selling point and perhaps an insurance policy, it hinders large-scale operations. Because of its diversity, for instance, bambara bean cannot be processed using a consistent formula and some consumers are put off. When you get right down to it, a bean of variable texture and taste has difficulty competing with the super-consistent Michigan pea bean, for example, all of which are identical in size, color, taste, and texture.

One serious limitation is the time needed to cook the dry seeds. Wherever firewood is scarce, this can pose a problem.

The seeds reportedly contain "flatus factors," which like their counterparts in common beans reduce, but don't eliminate, the food's desirability. A good 24-hour soak is said to reduce the effect.

NEXT STEPS

With a crop as neglected as this, almost everything needs doing. Following is a selection.[20]

Building a Bigger Market We are confident enough of the bambara bean's basic qualities to recommend that the first focus be the output end. Opening up opportunities for sales will produce an explosion of grower interest and almost automatically result in greater planting, greater research, and greater recognition all round. Opportunities for increased sales could be in the formal and informal sectors, urban centers, rural centers, exports, and commercial food processing. For farmers the key issue will be price. If they can achieve the same returns they get for other premium beans, this crop will emerge from hiding all across the continent.

The key to higher prices is strengthened demand. And marketing campaigns are one way to strengthen demand. This commodity above all else needs publicity. Even in tropical Africa, millions remain unaware of its existence, let alone its benefits. The information should be aimed especially at urban areas and the younger generation. It should be a typical consumer-awareness venture (not excluding endorsements by local celebrities). Adjuncts in this case might include recipes in various local languages and special dishes served in fancy restaurants and state dinners.

Processing can also help break through mental barriers. According to one

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[19] In this regard, a mechanized bambara-groundnut sheller is reportedly under development in South Africa.

[20] Other research ideas and a comprehensive review of this crop, including bibliography, can be found in Heller, J., F. Begemann, and J. Mushonga, eds. 1997. *Bambara groundnut:* Vigna subterranea *(L.) Verdc.* International Plant Genetic Resources Institute, Rome; available online via www.ipgri.cgiar.org/publications.

reviewer, Zimbabweans formerly viewed bambara bean as a famine food, fit for eating only as a last resort. However, when it became available in cans all that changed. Suddenly, it was seen as modern.

Any publicity campaign might be extended internationally. To consumers in North America or Europe canned bambara bean will look much like other canned beans. But it will take on a new mystique once they know that: 1) it was grown by impoverished women farmers, 2) it was grown organically, and 3) every purchase helps preserve an ancient heritage of biodiversity. The future could perhaps see a movement not unlike those aimed towards fostering shade-grown coffee or rainforest candies.

International food-relief agencies could help as well. Using local bambara instead of importing foreign beans would stimulate farmer interest, consumer confidence, and overall production.

In a related vein, the publicity programs should aim at broadening the crop's uses. In eastern and southern Africa, for instance, it is currently viewed as a snack food. Extending its use to include the main-course dishes will see hundreds of thousands of small farmers substantially increase production, profits, and prospects.

In modifying people's mindsets, it is important to develop better figures on the present production. One of our reviewers urges that governments stop burying bambara bean under "Other Pulses," and include it separately in their national agricultural statistics. This will, he says, enhance the crop's reputation and status in policymaking and development programs.

On-Farm Promotion Parallel to the public-awareness promotions, there needs to be farmer-awareness activities. Currently, many farmers don't plant bambara bean solely through lack of knowledge, confidence, or advice. In parts of its range, the limit is merely a lack of quality seed. Governments and seed suppliers should rectify this by multiplying whatever reasonable landraces are on hand. Also, extension agents should encourage farmers to set aside areas for producing bambara-bean seed for themselves and their neighbors. Although NGOs, commercial organizations, and extension services should assist in seed multiplication, farmer-to-farmer exchange programs could prove especially good mechanisms for upgrading this crop.

Genetic Resources and Breeding The genetic diversity needed to improve bambara bean is already on hand. Collections have been made across Africa, and the resulting seeds remain securely stored in facilities across Africa.[21] Therefore, in the long process of improving this crop, one

[21] The largest collection is held by IITA in Nigeria while a smaller collection is held at the Crop Research Institute in Ghana, along with several other locations in Africa. The collections differ markedly in general morphology, particularly size and color of seeds, number of pods per plant, and color of leaves. Specialists have declared that the existing germplasm collections hold insufficient population samples from Chad, Ethiopia, Niger,

starting point is this germplasm. Having come from different parts of the continent these seeds should demonstrate the genetic treasures within this species. Then, through judicious selection and breeding, the road to cultivars possessing broad adaptation to Africa's various environments ought to open up.

The plant's underground flowers make cross-pollination difficult, but attempts are nonetheless being made to breed in desirable characters, particularly high and stable yield, early maturation, and photo-insensitivity. These are important actions, but more are still needed to ensure that the crop moves forward with a broad-based and reliable genetic underpinning. They plants are self-compatible and largely self-pollinated (though ants may help increase pollination levels), so once a variety is found it should stay reasonably stable.

In part, parallel crop breeding activities are necessary because bambara bean occurs throughout Africa and occupies a vast array of different sites. Though this suggests a highly adaptable plant, there are indications that individual cultivars are site-specific. Tanzanian cultivars, for example, have yielded poorly in Zambia. Indeed, some from northwestern Tanzania failed in the drier climes and different soils of central Tanzania. For starters, the most effective research on improving this crop may be to concentrate on local landraces.

However, it is also important to separately sort out the photoperiod effects, and to create day-neutral types that will grow in different latitudes and seasons. Shuttle breeding could be the key to long-term success, as it was with the wheats that created the Green Revolution in Asian and Latin America. Moving seeds sequentially from location to location and discarding all but the best producers at each site quickly distinguishes the most resilient and adaptable types.

In part, too, parallel crop breeding activities are needed to produce different plants for different farming styles. Types suitable for large-scale mechanized farming are needed on the one hand, and types for small-scale cultivation by subsistence farmers on the other. It has been suggested that the targets be: a bunch ideotype for large-scale mechanized farming and a spreading ideotype for smallholders dependent on cereal-based subsistence systems where the plants are more scattered.

Although we've noted that adequate genetic diversity is on hand, more collections are needed on farms in Burkina Faso, Togo, and Nigeria's middle belt—a zone thought to include the greatest variation. Further, there is a need to collect the ancestral, pre-domestication wild form that is distributed in natural areas from Jos Plateau and Yola in Nigeria, to Garoua in Cameroon, and probably beyond.

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and Sudan. Begemann, F. 1988. *Ecogeographic Differentiation of Bambara Groundnut (*Vigna subterranea*) in the Collection of the International Institute of Tropical Agriculture (IITA)*. Wissenschaftlicher Fachverlag Dr Fleck, Niederkleen, Germany.

Horticultural Development Given the almost complete lack of tested information, the crop's agronomy deserves intensive study. This doesn't, however, demand a delay for research investigations: enough expertise already exists to raise the crop's productivity many-fold and quickly.

Part of that expertise is stored in the minds of Africa's farmers, and there is a need to assess their practices and adapt the best Africa-wide. On the other hand, part of that expertise is stored in the minds and manuscripts of peanut researchers who have no inkling their crop has an African cousin, let alone that their experience could help it. Peanut research is prominent in the United States, Brazil, Australia, and several African nations. Researchers there should include exploratory studies with the bambara bean. In this way, they will likely see how to quickly lift levels of production and utilization. As a bonus, they might reap powerful insights into the peanut plant.

In particular, the crop's management on a larger scale needs advancement. Investigations of mechanized cultivation and harvesting, and the overall adaptation of modern peanut-farming methods should be undertaken. Investigations into mechanized shelling and processing (especially canning) are more than justified. A machine to crack open pods could do more than almost anything to advance thie crop.

Although bambara bean is relatively free of pathogens and pests, research to identify cultivars more resistant to the major known threats could be most helpful. Trials should be made in ecological zones rife with the particular disease or pest. It is there that the plant's ultimate adaptability and resistance can best be determined.

Unconfirmed observations indicate that the crop can suppress striga, a parasitic weed particularly prevalent in Africa's sandy soils. In addition, as we've noted, the plant is said to thrive in laterite, the reddish acidic soil that is rich in soluble aluminum and toxic to many crops. And the crop reportedly does very well in sandy soils. Each of these capabilities deserves rapid assessment and promotion because each would be great value to Africa, just by itself.

Nutrition and Food Technology Nutritionists and food technologists—whether inside Africa or not—should pay close attention to this overlooked food plant. Huge gaps in the knowledge base still remain to be bridged.

For one thing, the micronutrients—both vitamins and minerals—need careful documentation.

For another, the overall digestibility needs checking. Antinutritive factors are likely to be present, and their levels during different stages of seed maturity need assessment. In addition, their fate during various types of cooking should be followed. Finally, their levels in different seed types need measuring.

For a third, aflatoxin levels should be assessed on bambara bean samples.

Given this cancer-causing chemical's threat to the safety of peanut, this would be a wise precaution.

Beyond those fundamentals, this food needs testing in programs engaged in fighting malnutrition. At least one researcher has suggested it could form the basis for special dietetic foods for children. In as much as the crop grows in some of the most malnourished nations, this should be followed up. Interesting in this regard would be head-to-head comparisons with soyfood counterparts.

As we've noted, the crop could find use in food industry. Processing methods such as canning, milling, popping, puffing, and protein extraction might lift it into many new markets. Snack foods are a special possibility. Possibilities for such processed foods in world trade should be considered.[22]

For such large-scale operations, the option of packaging boiled beans in pouches should be considered, as it might avoid the expense of metal cans. Solar heating and storage under anaerobic conditions (e.g. in sealed metal drums or plastic bags) could be effective ways to reduce post-harvest losses.

As noted, too, at least some seeds contain flatus factors. The levels of poorly digested sugars should be checked in a range of different strains. It's possibly a long shot, but it might lead to breeding lines with elevated digestibility and greater consumer acceptance.

The fact that the seeds are rich in soluble fiber deserves follow up. Other crops containing such substances are widely touted to reduce the incidence of heart disease and help prevent colon cancer. Psyllium and oats have turned into major international resources solely on the basis of possessing this same non-nutritious nutrient. Might a new bambara bean export line be developed around it too?

SPECIES INFORMATION

Botanical Name *Vigna subterranea* (L.) Verdc.

Synonyms *Voandzeia subterranea* (L.) Thouars.

Family Leguminosae Subfamily: Papilionoideae

Common Names

Afrikaans: dopboontjie
Arabic: gertere, guerte
English: bambaranut, bambara groundnut, Congo goober, earth pea, baffin pea, Njugo bean (South Africa), Madagascar groundnut, ground bean, earth bean, earth nut
French: voandzou, pois d'Angole, haricot pistache, pois arachide, pois

[22] This is not as farfetched as it may seem. The Zimbabwe company already mentioned filled an order from a food processor in California for a container of the dried beans.

Bambarra, pois Souterrain, vanzon,
Portuguese: mandubi d'Angola (Brazil)
Sierra Leone: agbaroro (in Creole)
Ghana: aboboi, akyii
Nigeria: epi roro, guijiya, gujuya, okboli ede
Hausa: juijiya
Ibo: okpa otuanya
Yoruba: epi roui
Sudan: ful abungawi
Central Africa: njogo bean
Kenya: njugu mawe
Zambia: juga bean, ntoyo
Malawi: nzama, njama
Zimbabwe: nlubu, nyimo, jugo bean
Madagascar: pistache Malagache, voanjobory
Ndebele: indlubu, ditloo
Shona: nyimo
Swahili: njugu, njugu mawe
Tsonga: kochane, nyume, ndlowu
Venda: nduhu, nwa, tzidzimba
Xhosa: jugo
Zulu: indlubu
siSwati (Swaziland): tindlubu
Indonesia: kachang Bogor,
Thailand: thua rang
Malaysia: kachang Manila (Manila bean), kachang tanah, nela-dakalai
Surinam: gobbe

Description

The plant is a herbaceous annual, often spreading or trailing, but also erect and bushy. It has a well-developed taproot with profuse geotropic lateral roots. New roots often appear where nodes contact soil. The fibrous lateral roots form nodules for nitrogen fixation. In association with appropriate rhizobia they usually nodulate well.

The stems are branched and hairy, with short internodes. The leaves are trifoliate and are borne on long slender petioles. The flowers spread out close to ground level on hairy peduncles, each producing one to three flowers. Most flowers are light yellow in color, although some are deep yellow (especially late in the day). After pollination, each small flower sends down a tendril, or peg, like a long root, which continues to burrow even after it has pierced the soil.

Like peanut, the plant then forms pods on, or just beneath, the ground. The pod achieves its mature size about 30 days after fertilization. The seed further develops in the subsequent 10 days. Most varieties have single-

BAMBARA BEAN BEYOND AFRICA

Bambara bean was known in Brazil as early as the 1600s, and its origin is clear from its name: *mandubi d'Angola*. Portuguese voyagers—most likely slavers—carried it across the Atlantic. Many crops were carried both ways between Brazil and today's Angola, Mozambique, Guinea-Bissau, Principe and Sao Tome. Indeed, from those germplasm swaps Africa received peanut, cassava, and maize—the three main foods that now feed the continent.

By a historical accident, the first botanical mention of the crop was by Marcgrav de Liebstad, who recorded it as a native Brazilian crop in 1648. Then for another 158 years the crop was lost to the literature. It was only in 1806 that another botanist (Du Petit-Thouars) stumbled across the same species growing in Madagascar, under the name *voanjo*. Following that rediscovery, it took about another century of botanical sleuthing to finally confirm that the plant was truly African.

In addition to Brazil at least two parts of Asia—West Java and southern Thailand—also cultivate the crop. Although produced only on a micro scale, this African legume serves Indonesian and Thai consumers as a soup vegetable, a snack, and a dessert ingredient. How and when it reached Southeast Asia has so far not been explained.

In Malaysia, where the plant is known as *kacang poi*, it is mostly consumed as boiled nut (similar to peanut). Perlis, Kedah, and Kelantan, states bordering Thailand, are apparently the only ones to grow it so far. The crop is produced like peanut, but is said to yield less. It is commonly marketed as raw nuts at farmers and night markets. In addition, small amounts are imported from Thailand.

seeded pods, but ecotypes collected in Congo frequently had pods with three seeds.[23] Mature pods are indehiscent, often wrinkled, ranging from a yellowish to a reddish dark brown color. The seeds are round, 1-1.5 cm in diameter, and come in colors varying from white to creamy yellow, brown, purple, red, and black. Most are a single color, but some are mottled, blotched or striped.

Distribution

Within Africa Although wild types are still to be found in tropical eastern Africa, the crop is believed to have originated in the region encompassing northeastern Nigeria and northern Cameroon. It is today

[23] Goli, A.E. and N.Q. Ng. 1988. Bambara groundnut multi-location yield trial. Pp. 11-12 in *Annual Report, Genetic Resources Unit*, IITA.

cultivated throughout tropical Africa's drier areas, including Madagascar. In southern Africa, Zimbabwe is the center of production.

Beyond Africa Botanists in earlier times identified specimens in a number of tropical locations, including India, Philippines, Fiji; Sri Lanka, New Caledonia, and Surinam. Whether the plants still exist there is unknown; probably they were in botanic gardens and research institutions, rather than farmers' fields.

The present degree of cultivation outside Africa is basically negligible. However, the crop still grows in Brazil as it has since the 1600s. It is also cultivated in West Java and southern Thailand. Although produced only on a small scale, this African legume serves Indonesian and Thai consumers mainly as a soup vegetable, a snack, and a dessert ingredient.

Horticultural Varieties

Strictly speaking, there are no formal varieties. Every planting now uses mixtures of landraces mainly identified by the size and color of the seed and the shape of the leaf.

Environmental Requirements

The plant grows best in climates used for growing peanuts, maize, millet, or sorghum. It needs abundant sunshine, high temperatures, at least four frost-free months, and frequent rains during the period between sowing and flowering.

Daylength Most cultivars are adapted to short days of the tropical and subtropical latitudes.

Rainfall An evenly distributed rainfall in the range 600-1,000 mm encourages optimum growth, but satisfactory yields can be obtained where the dry season is pronounced. Except during the flowering period, heavy rainfall causes no problems.

Altitude Satisfactory yields can be obtained at elevations up to at least 1,600 m.

Low Temperature For optimal growth the temperature requirement is reported as 20-28°C.

High Temperature The plant seems little fazed by high temperatures. It grows, for instance, where temperatures top 40°C; areas, in other words, unsuitable for many leguminous crops.

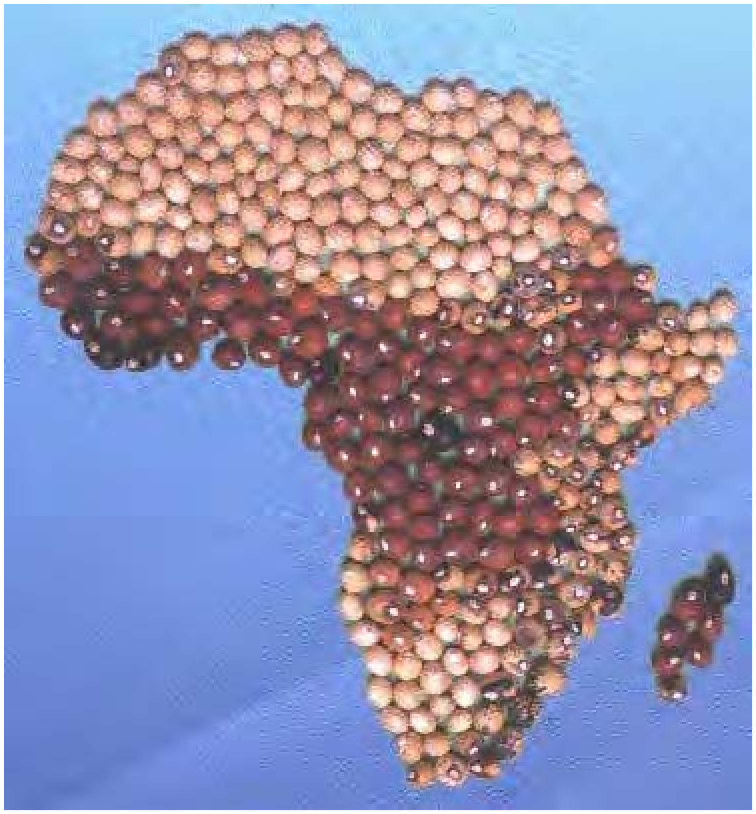
Soil The crop must be planted in loose, light soils to facilitate both the nitrogen-fixing bacteria in its root nodules and the development of the buried seeds. It also eases the task of digging up the pods. Any well-drained soil is suitable, but light sandy loam with a pH of 5-6.5 and medium to low fertility is said to produce the most seeds.

Related Species

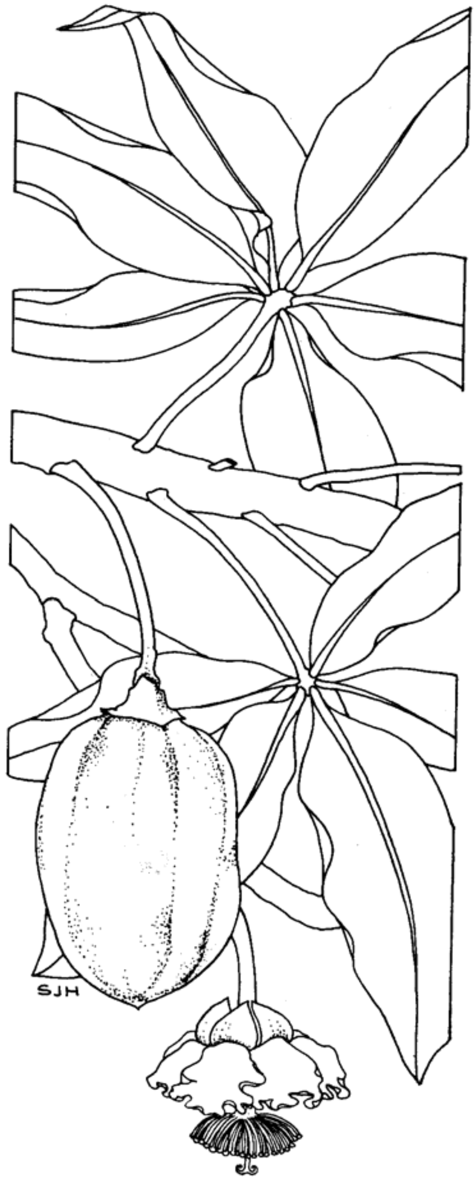
A closely similar plant, the groundbean or Kersting's groundnut,[24] also deserves attention. Its leaves are broader than those of the bambara bean and the plant is less robust. Though the pods develop underground, the seeds resemble common beans and are usually white, brown, black, or speckled in color. Their protein occurs in good quantity (19-20 percent) and is rich in the essential amino acids lysine (6.2 percent) and methionine (1.4 percent). Grown in both high-rainfall and savanna areas in tropical Africa, this groundbean survives even drier areas and is even more obscure than the bambara bean. Although the seeds are tasty, they are small and yields are poor, disadvantages likely to be correctable with appropriate research. Achieving that could unleash a high-lysine, high-methionine crop of potentially great nutritional significance.

Another virtually unknown relative is found in tropical Africa is *Vigna poissoni* (synonym *Voandzeia poissoni* Chev., also a synonym for, at least, some forms of Kersting's groundnut). Its underground beans are supposedly eaten in Benin, but we are unaware if even one agricultural or food scientist has looked into this species yet.

[24] *Kerstingiella geocarpa* Harms or *Macrotyloma geocarpum* (Harms) Maréchal & Baudet



(Werner Schenkel)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BAOBAB

A very, very long time ago, say some African legends, the first baobab sprouted beside a small lake. As it grew taller and looked about it spied other trees, noting their colorful flowers, straight and handsome trunks, and large leaves. Then one day the wind died away leaving the water smooth as a mirror, and the tree finally got to see itself. The reflected image shocked it to its root hairs. Its own flowers lacked bright color, its leaves were tiny, it was grossly fat, and its bark resembled the wrinkled hide of an old elephant. In a strongly worded invocation to the creator, the baobab complained about the bad deal it'd been given.

This impertinence had no effect: Following a hasty reconsideration, the deity felt fully satisfied. Relishing the fact that some organisms were purposefully less than perfect, the creator demanded to know whether the baobab found the hippopotamus beautiful, or the hyena's cry pleasant-and then retired in a huff behind the clouds.

But back on earth the barrel-chested whiner neither stopped peering at its reflection nor raising its voice in protest. Finally, an exasperated creator returned from the sky, seized the ingrate by the trunk, yanked it from the ground, turned it over, and replanted it upside down. And from that day since, the baobab has been unable to see its reflection or make complaint; for thousands of years it has worked strictly in silence, paying off its ancient transgression by doing good deeds for people.

All across the African continent some variation on this story is told to explain why this species is so unusual and yet so helpful. Indeed, dozens more stories surround the baobab, a species that not only incites imagination but also induces something akin to reverence. Senegal chose it for its national tree and throughout the lands below the Sahara the sight of a baobab inspires poetry, legend, compassion, even devotion. Africans everywhere almost instinctively protect each and every one.

Seen from a distance, the results of the creator's prank come into clearer perspective: baobabs certainly do seem to grow with their roots kicking the breeze. From the top of the trunk the boughs splay upward at a sharp angle, and they are crooked enough to seem like they should be underground. This eye-catching profile makes each baobab unique, and no matter how many you've seen before the shape seems always fresh.

Yet beyond the charms this tree conjures in people's minds lies a beguiling reality. Of all nature's living entities this is one of the most fascinating. For one thing, it may be exceptionally long lived, with some individuals claimed to be over 1,000 years old.[1] It is also among the biggest and bulkiest of all living organisms, having a trunk sometimes half as broad as it is high.[2] This squat stalk, its smooth surface pocked and slit as if stigmatized, is often hollow. Some monstrous specimens actually enclose a trunk space bigger than that found inside a small house. In dry areas they are commonly co-opted as village cisterns. A single bulbous stem has been known to store as much as 10,000 liters of fresh clean water. No wonder another name for baobab is bottle tree.

It is also one of the most useful living entities. On a practical level, the Africans' veneration arises because the baobab is vital to life. The bark fuels cooking stoves, pottery kilns, and baking ovens. The flexible fiber found in the layer immediately beneath the bark provides cord and coarse fabrics. The fruits are eaten with food or stirred into drinks, and provide exceptional quantities of vitamin C and other nutrients. The seeds are roasted and made into a sort of creamy butter.

The living trees are useful in their own right—not only providing shade but often providing the only splendor in an otherwise sere landscape. They also constitute handy landmarks for travelers,[3] gathering points for villagers, and silent witnesses to long abandoned villages. Nothing grows around the base, a feature emphasizing the profile, not to mention the self-sufficiency, solitude, and apparent strength of this surprising species.

In a separate volume we detail baobab fruit as well as most other products from the tree. Here we focus on the leaves and their uses.

Baobab leaf is a staple of many populations in the savanna lands just beneath the Sahara. In most places between the westernmost tip of Senegal and Lake Chad half a continent to the east this leaf vegetable is among the most common of foods. Bursting into foliage a little before the rains begin, the trees remain green until a little after the rains have ceased. In a food class renowned for transitory availability, baobab is thus a leafy vegetable that yields through a very long season.

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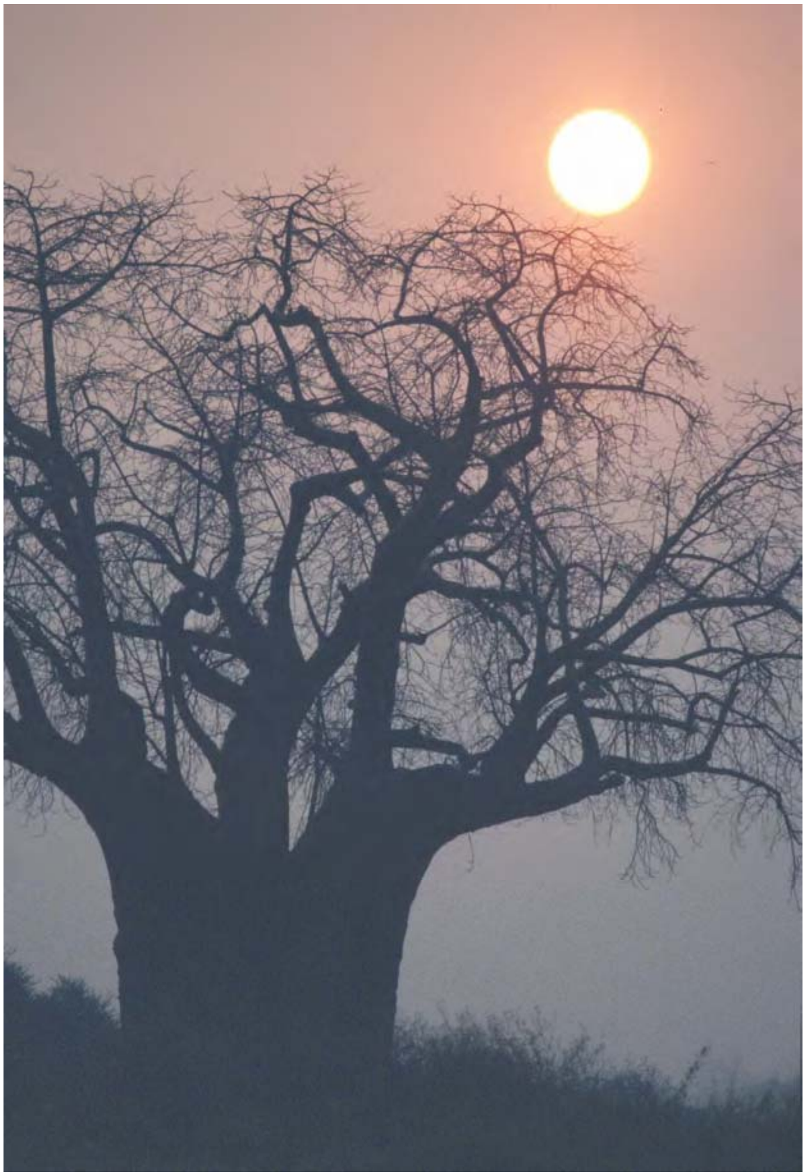
[1] Although the trunk forms growth rings, they are laid down irregularly, so a baobab's age is difficult to determine by this means. Carbon dating has put the ages of some specimens at 2,000 years, and there are claims that others have seen six millennia pass.

[2] Specimens 18 m tall with trunks 9 m across have been measured. They often form classic looking half-arches reminiscent of the flying buttresses on European cathedrals.

[3] They provide landmarks even for mapmakers—indicating locations on map sheets in otherwise featureless landscape. Large baobabs are, for instance, indicated on 1:200,000 map sheets in Mali.



Nature's most recognized silhouette? Baobabs are so distinctive there is little chance of ever mistaking one. These majestic trees are found throughout much of Africa. It is hard to conceive anything more promising for Africa's long-term future than a native tree beloved by the people, that seemingly lives forever without much maintenance, and that provides nutritional food (William F. McComas, photographed in Tanzania's Tarangire National Park)

Strangely, it is only in West Africa that baobab leaves contribute to diets in a major way. Eastern and Southern Africa have the tree but seldom consume the leaves. In the continent's western half, however, thousands of tons are consumed annually, and baobab greens are a commonplace in the markets as well as the daily meals of millions.

Baobab leaf is sometimes steamed and eaten as a side-dish like spinach, but most goes straight into soups, stews, sauces, relishes, and condiments that end up being poured over the yam, cassava, maize, millet, sorghum, and so forth to complete the main dish.[4] A recent survey in Mali found that baobab leaves occurred in 41 percent of these "soups."[5] This widely used name does something of an injustice to such concoctions, which are more akin to sauces. The leaves not only add flavor and nutritive value they thicken the mixture and give the dishes their slightly slippery texture as well as their popularity. Although baobab leaf is the most common base for these sauces, many other things, including eggplant, okra, jute,[6] tomato, onion, green peppers, and (when available) fish or meat, are also tossed in. Throughout that vast region this vegetable blend ladled like gravy over starchy staples is the most common cooked food of all.

In collecting their leaves for the evening meal, people are constantly plucking and pruning the trees, with the result that baobabs never get a chance to look natural and complete. Indeed, across West Africa they become so thoroughly picked over they look ragged, ratty, or even in the final phase of succumbing to some wasting disease.

Following the flush of new leaves early in the rainy season any surplus harvest is put aside to dry. In desiccated form, the leaves keep well—surprisingly without losing their glutinous polysaccharides—and many months later they can be brought out and used to thicken soups just like new.

In cities, where baobabs aren't available for the picking, the leaves for the evening meal must be purchased. For many people finding the baobab money becomes a never-ending struggle: Making baobab-leaf sauce can cost the equivalent up to even a dollar a day, a fearsome price in that area, where making more than that for a day's work is rare. On the other hand, countrywomen derive small but important income from selling the leaves.

In nutritional power baobab leaf is quite surprising. According to various reports it contains 11 to 17 percent crude protein and with an amino-acid composition comparing favorably with that considered the ultimate for human nutrition. Isoleucine, leucine, lysine, phenylalanine, tyrosine, threonine, tryptophan, and valine all occur in adequate amounts. The lysine

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[4] Baobab is, for instance, a major food of the Hausa-speaking peoples. A traditional Hausa lunch includes danwake, which is typically a blend of sorghum, sweet potato, cassava, potash, peanut oil, dried chile, cowpea, and baobab leaves.

[5] The next most popular, at 26 percent, was okra—a crop dealt with in Chapter 16.

[6] Although the jute used to make sacking can be eaten, the species cultivated as a vegetable is its relative *Corchorus olitorius*.

level is especially notable, since people usually eat baobab leaf along with cereals or roots, which are both comparatively deficient in this critical dietary ingredient. Wherever meat, milk, or eggs are hard to come by or excessively costly—which means most places—the leaves contribute a protein of vital quality.

Beyond quality protein, young and tender baobab leaves contain good levels of provitamin A, and it is notable that the trees thrive in the kind of dry and impoverished locales where a lack of vitamin A constitutes one of the worst nutritional deficiencies. In addition, the levels of both riboflavin and vitamin C have proved adequate in the leaf samples tested so far.

The leaf is moreover a good source of minerals, including in its tissues calcium, iron, potassium, magnesium, manganese, molybdenum, phosphorus, and zinc. A detailed analysis so convinced the authors that they wrote: "in terms of both quality and quantity, baobab leaf can serve as a significant protein and mineral source for those populations for whom it is a staple food."[7]

All in all, then, this is a tree with a capability to hold its own against cabbage, spinach, carrots, and the other vegetables that now capture the focus in textbooks, scientific reports, and foreigners' image of first-class greens. Seen in overall perspective, baobab is a native resource that provides the continent a tree cover while providing the people food. And, given some support and attention, it could contribute a lot more to the environments, nutrition, economies, and personal income (particularly women's income) of many—if not most—African nations.

Of particular importance is the leaves' potential to help women and children who are currently beyond the reach of vitamin-support programs. In Sub-Saharan Africa, some 3 million children suffer blindness caused by insufficient vitamin A. Two-thirds of those die from increased vulnerability to infection. Their mothers are hardly better off: The World Health Organization reports that women suffering vitamin A deficiency face a significantly greater risk of death during pregnancy. Vitamin A deficiency is also common in AIDS patients, and is associated with an increased mortality rate. Baobab leaf just might be a key vehicle for delivering such people from the evil of malnutrition.

PROSPECTS

At this moment, rural peoples' dependence on baobab products seems to be rising. Probably, though, this is not due to greater appreciation for the tree but due to soaring populations, falling economies, and shrinking forests. The potential for boosting this species into a vastly greater vegetable crop would

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[7] Yazzie D, D.J. VanderJagt, A. Pastuszyn, A. Okolo, and R.H.Glew. 1994. The amino acid and mineral content of baobab (*Adansonia digitata* L.) leaves. *Journal of Food Composition and Analysis* 7(3):189-193.

Well-picked-over baobab forest in Senegal. The leaf of the much beloved baobab is a staple of the savanna lands below the Sahara. In an area stretching across half the continent, this vegetable ranks among the commonest foods. Bursting into foliage a little before the rains begin, the stately trees remain green and edible until a little after the rains have ceased—often half the year. In addition, any surplus harvest can be dried, in which form, the leaves keep well even under the climatic challenges of rural Africa. (Sherman Lewis)

thus seem to be exceptional.

The main first use is likely to be small-scale commerce and subsistence use. Traditionally, baobab has not been deliberately cultivated for major commercial production, however farmers in Burkina Faso and Senegal have begun organizing its production for the local markets. Reportedly, these ventures have proven profitable.

Furthermore, extending the use of baobab leaf to regions beyond West Africa offers possibilities for enhancing both the crop and its benefits to nutrition, prosperity, and the environment. In addition, as we have said, there are excellent prospects for using baobab in health campaigns, playing off the wisdom of traditional diets.

All in all, this is a species that can get to the heart of the humanitarian needs of the most malnourished continent, not to mention the heart of rural poverty and environmental destruction.

Within Africa

As a species that speaks to the African spirit—one that, in a sense, stands for Africa—the baobab has promise almost everywhere, but the commercial and humanitarian prospects are somewhat more limited.

Humid areas Uncertain prospects. Most observers would today dismiss the baobab for cultivation as a humid lowland resource. However, in certain areas the trees thrive where annual rainfall reaches 1,250 mm, actually growing with almost twice-normal speed. Indeed, along the Kenyan coast baobab grows vigorously where annual rainfall ranges up to 2,000 mm. Thus, on the issue of its tolerance of lowland tropical conditions a grave misconception might possibly be inhibiting expectations and initiatives.

Although heat and humidity may slash fruit production, they don't affect the leaves. They may in fact force even greater production of foliage. Of course, this tree grows in the open and cannot take the shady conditions of a forest.

Dry areas Excellent prospects. Baobab is common throughout West Africa's savannas, where the Sahara Desert to the immediate north is the dominant climatic influence. In this often-parched precinct baobab is not only the biggest but also arguably the best tree around. It has even been dubbed "Mother of the Sahel." People like the leaves and the production in this zone could readily be boosted for the benefit of children's eyesight, the environment, the savanna scenery, AIDS patients, and all who eat there.

Upland areas Unknown prospects. The baobab normally occupies sites below 600 m elevation, which has been considered the species' upper limit. Nonetheless, there are indications that—within reasonable limits of temperature and rainfall—niches to accommodate these trees could be found at elevations far above that supposed ceiling.

Beyond Africa

Although the baobab grows satisfactorily outside Africa, it seems unlikely to become a significant vegetable resource in locations where it is not now employed in that manner.

USES

In overall utility, perhaps no tree on earth surpasses baobab.

Vegetable As mentioned, the young leaves are used as a soup ingredient. Large quantities are consumed. The amount used in preparing soup, for example, varies depending on the taste of the cook and her level of prosperity, but one survey of 831 preparations in three Zaria (Nigeria) villages found that baobab leaf constituted between 2 and 3 percent of the whole soup.

Typically, leaves are ground up and sprinkled into the pot in which sauces are being prepared. Taken all round, this is the main form in which leaf is employed. Hausa-speaking peoples in particular consider it the main ingredient of a soup called miyar kuka (kuka being their name for dry baobab leaves). But all across West Africa these popular baobab-leaf soups are most often labeled with the Wolof name, lalo.

In Ghana baobab-leaf soup is used as weaning food. Research has shown it to be of such nutritional quality that it may be therapeutically useful in the management of protein-calorie malnutrition—the biggest baby-killer of all, and a common feature across Africa.

Forage Baobab leaves are among the livestock owner's favorite forages. They become vitally important at the beginning of the rainy season, a time of year when the old pasture has been eaten out and the new has yet to regrow. The tree's roots, when tapping into underground moisture, help generate an early flush of foliage that can make the difference in bridging this feed gap. The leaves are also eaten by large caterpillars that are themselves a valued food.

Medicinal Uses Baobab leaf powder is credited with various medicinal powers and is commonly taken as a general tonic as well as a treatment for anemia and dysentery. The leaves are also used in treating other afflictions: asthma, kidney and bladder disease, insect bites, fevers, malaria, sores, and even copious perspiration.

Beyond the leaves, there are of course other uses for the baobab. These are highlighted in the companion volume, but can be summarized as:

Fruits Reaching almost the size of melons, baobab fruits enclose packets of chalk-like pulp with an agreeable acidic taste. That floury solid is peculiarly refreshing, a feature especially appreciated in the hot zones where the tree mostly occurs. Although much goes into tasty and nutritious drinks, most is eaten with milk or with milk and porridge. The fruits are also sucked as a snack or ground into flour and added to cereal dishes. The seeds are not only roasted and made into a sort of creamy butter, they are used to strengthen soups.

Seeds Embedded in the fruit pulp are seeds whose kernels not only are tasty but high in protein. They too are widely eaten. They are sometimes prepared by roasting. Indeed, during the "hungry season," roasted baobab seeds become many people's staple. Their flavor has been likened to that of almonds.

Flowers As a source of nectar baobab flowers are excellent. All in all, these trees contribute greatly to Africa's honey supply.

Trunks The bark often forms cavities deep enough for animals, and even people, to find homes. The gigantic trunk is occasionally coopted for use as storage sheds, bus stops, bars, dairies, toilets, watchtowers, grain stores, shelters, stables, or even tombs. Water stored inside may keep for months or even years without fouling (as long as the hole in the trunk is carefully covered to block contamination from the outside).

Roots The tender root of the very young baobab is edible. Older roots are not, but they provide a strong red dye.

Amenity Plantings Baobabs are planted for shade, shelter, boundary-markers, and general beautification. They typically cluster around villages, but each one—even standing alone and unattended in the vast savanna—is individually owned or at least commandeered by "squatters" who first prune off the branches—partly to increase productivity, but mainly to secure their claim to the tree for the season. Large groupings are either part of living villages or silent witnesses to dead ones. Sometimes it is hard to tell whether people naturally settle close to these useful trees or vice versa.

Fiber The stringy inner bark yields a particularly strong and durable fiber that provides such things as rope, thread, strings for musical instruments, and a paperstock tough enough for bank notes. Some is woven into fabrics that are valued for making (among other things) the bags used for hauling and storing everyday goods. These fabrics can be waterproof, and Senegalese artisans weave them into rainhats and even drinking vessels.

Fuel The thick bark, the fibrous husks of the fruit, and the dense shells of the seeds make useful fuels. Although the bark is burnable, the spongy material making up the bulk of the trunk (i.e. the part inside the bark) is usually too sodden to even smolder until thoroughly dry.

NUTRITION

Baobab leaf provides at least four nutritious ingredients: protein, vitamins, minerals, and dietary fiber.

Protein As noted, fresh leaf samples are protein rich. Leaves analyzed in the above-mentioned report contained 10.6 percent protein.[8] The amino-acid composition—the one comparing favorably to the "ideal"—was valine (5.9 percent), phenylalanine/tyrosine (9.6 percent), isoleucine (6.3 percent), lysine (5.7 percent), arginine (8.5 percent), threonine (3.9 percent), cysteine/methionine (4.8 percent), and tryptophan (1.5 percent). In sum, there were adequate amounts of all the essential amino acids excepting the two, cysteine and methionine, containing sulfur.

Vitamins Baobab leaves contain a very high level of the carotenoids that give rise to vitamin A. The actual amounts (9-27 mg per kg) depend on the tree and on the method of drying. The carotenoids are not unlike those found in carrots (and mangoes), but are less concentrated and less available than their carrot counterparts.[9]

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[8] Other researchers have reported up to 15 percent protein. Measurements are on a dry-weight basis.

[9] About 1600 ug./100 g retinol equivalent. Becker, B. 1983. The contribution of wild

Recent research determined the levels of provitamin A for various leaf types, drying methods, and processing systems.[10] It was found that drying the leaves in shade rather than sun doubled the leaf powder's provitamin A content—a very important discovery for those using baobab in health campaigns. The age of the tree had no effect on provitamin A levels but leaves from small-leafed trees contained more than from large-leafed trees.

Minerals The leaf samples are also high in ash (9-13 percent), which includes minerals such as calcium, magnesium, manganese, potassium, phosphorus, iron, sodium, and zinc. In certain samples, however, some of these elements occurred at lesser levels, probably reflecting deficiencies in the soil where the particular tree grew. One test indicated that 100 g of baobab leaves provide about three times the daily calcium requirements, twice the daily magnesium and copper requirements, and four times the daily manganese requirement. It is unclear how available these minerals are in fresh or processed leaves.

Fiber The leaf is also high in crude fiber, with levels of 15 to 18 percent measured. They also have an important amount of mucilage.[11]

HORTICULTURE

Little is known about how best to cultivate and care for baobab. Whereas the tree is common and well distributed throughout the Sahelian and Sudanian zones, few of the specimens there were deliberately planted—most arising as part of the natural system and subsequently preserved when farmers cleared the land. Concentrations of deliberately planted trees occur mainly in and around village sites.

We have earlier noted that Africans everywhere almost instinctively protect each and every baobab. Part of the reason, of course, is that the trees supply food and traditional medicines for both humans and their livestock. This resulting parkland system, in which the fields are everywhere dotted with trees, is the most widespread form of agricultural production over much of West Africa. Moreover, the practice of fallowing the land after cropping it for several years inadvertently helps native trees such as baobab to regenerate.[12]

Although this protection and natural regeneration are currently the main means of fostering baobab, the species can be propagated from seed. Simple

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planta to human nutriton in the Ferlo, Northern Senegal. *Agroforestry Systems* 1:257-267.
[10] Information from J. Scheuring.
[11] Gaiwe, R., T. Nkulinkiye-Neura, E. Bassene, D. Olschwang, D. Ba, and J.L. Pousset. 1989. Calcium et mucilage dans les feuilles de *Adansonia digitata* (Boabab). *Int. J. Crude Drug Res.* 27:101-104.
[12] Farmers fallow land mainly to relieve weed pressure and restore soil fertility. However, they do protect baobab trees that emerge as a result.

treatments are needed to overcome a reluctance to germinate in a timely manner. After a 5-minute soak in boiling water the seeds germinate uniformly and usually within three weeks.

Transplanting bare-root seedlings is satisfactory. For example, on the Seno Plain, along Mali's border with Burkina Faso, villagers often raise baobabs within their own courtyards and nurture the seedlings until they are 2-3 m tall, then transplant them to the edges of their fields.

Despite a reputation for slow growth, baobab seedlings on favorable sites have been known to reach 2 m in height in 2 years and become 12 m tall in 15 years. Although far above the norm, this shows the potential in the plant given horticultural attention.

Seedlings and young trees need careful protection. In fact, in the open savanna comparatively few small baobabs are ever seen, mainly because they fall victims to cattle, goats, ground fires, or overzealous individuals picking them to death for soup leaves.

Mature trees, however, have few enemies. No serious pest or major disease is known. Neither cattle nor goats do serious harm. Not even overzealous pickers can seemingly set back a healthy old baobab. Being a trunk-succulent, the tree resists both fire and drought. However, lightning, severe winds, and (in southern and eastern Africa) elephants can break the branches and bring down even the biggest of these botanical monarchs.

HARVESTING AND HANDLING

There is no secret about harvesting baobab leaves. People (mostly small boys) literally clamber over the trees, plucking off every young leaf within reach. Ladders of steps are often slashed into the side of trees to allow easy access to their upper stories. Many trees are kept basically denuded throughout their life. Some are pollarded, their top branches cut back to the trunk to induce a dense growth of new shoots. In both cases, flowering is suppressed and, perhaps because of that, the leaves sprout in abundance.

Because the leaves are available only during the rainy season, women dry any surplus and store it for use up to a year later, for times when vegetables are not only difficult to find but expensive. This propensity for easy storage also allows the leaves to be sold at the time when the traders pay the best prices. In good years this provides a small, but important, source of income.

In better-watered zones or in village gardens where each tree can be pampered through the dry season, baobabs prosper and often remain in foliage year-round.

LIMITATIONS

Although the leaves are rich in various nutrients, the quantities touted in research reports might not (at least in theory) reflect those actually reaching

the body. At present, no one knows about the digestibility of the different ingredients, but it is possible that phytic acid, oxalic acid, hydrocyanic acid, and tannins occur in high enough levels to interfere with the body's use of proteins and calcium.

Researchers in Mali discovered that the baobab powders on sale in public markets differed widely in nutrient content. They urged consumers give preference to those with darker green color and a good all-round baobab-leaf smell. "Based on its provitamin A content," they wrote, "baobab-leaf can be very effective at saving eyesight, but only as long as care is taken to handle the leaves in ways that preserve the vitamin. To maintain a high level of provitamin A level in dried leaves, it is important NOT TO DRY THE LEAVES IN THE SUN. Leaves dried in the sun have only half the provitamin A levels of leaves dried in the shade. [Also] it is recommended to store dried whole leaves rather than dried leaf powder in order to maintain good provitamin A levels. Provitamin A tolerates cooking, but is degraded by overcooking."

NEXT STEPS

A tree as productive and as important to people as this one is worthy of massive and pan-African research. Programs dealing with food, nutrition, forestry, agriculture, agroforestry, rural development, home economics, horticulture, and other subjects should embrace this species as a potential tool for helping achieve their individual goals. Combining the traditional, Africa-wide knowledge with modern scientific understandings could boost baobab to a far greater furnisher of food from Senegal to Mozambique and Madagascar.

This tree is already so well known that basic research is not essential to progress. Existing knowledge and the germplasm on hand can be used to mount planting and protection programs throughout its range. These can be big or little, concentrated or dispersed, rural or suburban.

Protection As noted in the volume on Africa's cultivated fruits, baobab is a candidate for self-motivated forestry. Indeed, if a few people take the initiative, it is not inconceivable they will spark an Africawide "Baobab Movement." Mass-producing saplings for the rural poor seems a good start. Such an endeavor would eventually do more than just feed the growers; it could create a critical mass of trees for producing leaves (as well as fruits and bark fiber) on an industrial scale. The tree would then move from a beloved but scattered village companion into a major continental resource. Although one must wait years for the fruits to form, leaves sprout from the start and the leaf harvest can begin after only brief delay.

One way to foster immediate increases is to raise the juvenile survival rate. With their slim stems and simple leaf form, saplings look too handsome to be baobabs. Thus, although old baobabs are venerated as personal

property, young ones go unclaimed, and quickly fall to ground fires, goats, and galoots stripping the leaves for dinner. This ignorance and mindless plunder are major constraints to further development and need to be reduced by programs that enlighten the populace to the potential inherent even in the skinny little young trees.

To outsiders, West Africa's tree-dotted savannas may look almost like recreational areas, but they are in fact nutritional ones. Products from various woody species in this parkland agroecosystem feed the rural population throughout the year and also contribute snacks during the period when other foods are scarce. This trees-and-farmland combination is an agricultural system that needs to be preserved; focusing on baobab is one way to help bring that about.

Education Whereas millions of people use baobab, few are aware of its notable health benefits. Although vitamin A deficiency is a chronic health problem in places such as rural Mali, the curative nature of baobab leaves goes almost unappreciated by the masses. In the fight against malnutrition these leafy materials offer sweeping future advances. They are on hand, they are known, and they can be marshaled to help children and others. This can be brought about through education, not excluding advertising.

One reason why more baobabs aren't planted is that people believe the tree grows so slowly that they'll never see the results. In addition, many people refuse to plant any species that regenerates spontaneously—why waste effort when nature will do the job for you. Again, education could be employed to motivate millions to plant more baobabs.[13]

In some areas cultural taboos may slow this species' greater use. In parts of the Gambia, for instance, baobabs are considered too evil to plant nearby. And in Mali during October and November prices for the leaves drop because it is said that during that "cool" season they cause the lips to crack. There is a need for broad education on what we really know about baobab—and what we don't.

Expanding the Use Although among the most widespread and most appreciated native plants, only West Africans use baobab much as a vegetable. Elsewhere, the trees abound but the leaves go uneaten. This opens new possibilities, of course, but before the production of leaves is promoted outside West Africa it would be wise to determine why they are rejected there now. According to one report, the trees used for vegetable purposes derive from a glabrous variety, with hairless leaves. The author implied that the tomentose variety, whose leaves are covered in down, furnish good fruit but bad (in the culinary sense) leaves. This perhaps explains the strange

[13] Actually, this attitude has already begun changing. "On my last two trips through Mali and Burkina Faso," one of our reviewers wrote, "I was very impressed by the number of baobab I saw growing in peoples kitchen gardens."

dichotomy of only one region eating the leaf. Should this observation prove true, then the hairless (good-vegetable) types and the hairy (good-fruit) types should be tested throughout the continent. This would involve a swap of germplasm likely to benefit all.

Nutritional Research With their 15-percent crude protein content, the leaves should be a useful source of this vital food type, but the crude fiber and tannins may reduce its digestibility. This needs investigation.

Similarly, the leaves are rich in calcium, but how much is absorbed by the body is uncertain because the leaves also contain gums that may impede its absorption. Phytic acid and oxalic acid, which are known to adversely affect their mineral utilization but whose levels are probably only marginally problematic, may also affect the availability of calcium, not to mention magnesium and iron.

Studies of the fate of vitamin C under various food-processing regimes would provide helpful guidance for best processing practices.

Baobab-leaf could become an important export, but any formal trade will require better governmental policies as well as better processing. The first step is to learn the potentials of the various products as well as the constraints associated with their manufacture and marketing.

Horticultural Development In baobabs grown for edible leaves the selection of elite types is less important than in those grown for fruits. Nonetheless, it seems well worth searching for highly productive forms that can foster and facilitate the species' progress toward becoming a better vegetable resource. Selection for leaf quality is the necessary research ingredient. Issues might include flavor, digestibility, carotenoid content, and ability to make soups with just the right slipperiness on the tongue. As noted, trees with small leaves have been recommended.

Vegetative propagation would be useful for making such advances, and the best techniques need to be worked out. This alone will foster new plantings, not to mention new profits and perceptions.

The plant's ecological tolerances and preferences are poorly understood. Although it appears far from picky about where it grows, at least one researcher has noticed "a tremendous response to choice of planting site, even to microsite."

On the surface, this would seem a good species for developing miniature gardens, as has been done with apples in England. By keeping the trees topped and pruned to human height, the leaves would be always within easy reach. Should this prove feasible, baobabs could be grown and plucked like tea plants. Women and girls could then participate equally in the harvest.[14]

[14] This may be somewhat fanciful: One reviewer wrote: "I'm a bit skeptical of this as the tree's crowns are not very full. A stunted tree would most likely have very few leaves." The key would be pruning at a very young age and, perhaps, the identification of plants

SPECIES INFORMATION

Botanical Name *Adansonia digitata* Linnaeus[15]

Family Bombacaceae

Common Names

Afrikaans: kremertartboom
Arabic: hahar, tebeldis; fruit: gangoleis
Bambara: sira, n'sira, sito
Burkina Faso: twege (Moré)
English: baobab, monkey bread, Ethiopian sour gourd, cream-of-tartar tree
French: baobab (tree); pain de singe (fruit), calabassier, arbre aux calebasses
Fulani: bokki, bokchi, boko
Ghana: odadie (Twi, in the south), tua (Nankani, in the north)
Jola: buback
Kenya: mbuyu (Swahili); mwamba (Kamba); olmisera (Maasai); muru (Bajun);
Malawi: manyika: mubuyu
Malagasy: Bozo (Sakalava dialect)
Mandinko: sito
Manyika: mubuyu
Ndebele: umkomo
Hausa: kuka (dried leaves), miya kuka (soup)
Yoruba: luru
Portugese: imbondeiro
Shona: mayuy, muuyu, tsongoro (seeds)
Sudan: tebeldi, humeira
Swahili: mbuyu
Tsonga: shimuwu
Tswana: mowana
Venda: muvuhuyu
Wolof: bui, lalo (leaf powder)
Zulu: isimuhu, umshimulu

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with many leaf buds low on the trunk.

[15] The genus was named for the French naturalist, Michael Adanson (1727-1806), who was among the first to study the botany of Senegal. He coined the word "baobab" and also devised a system of classifying and naming plants based on all their physical characteristics and emphasizing families. To this, the Swedish botanist Carolus Linnaeus was much opposed, and eventually his own system superseded Adanson's. Nonetheless, Linnaeus honored his rival by naming the tree's genus *Adansonia*. Linnaeus sometimes selected names meant as insults, so the fact that baobab is fat and ugly might also have been in his mind.

Description

Baobab typically grows up to 20 m tall and its sharply tapered, but very swollen, trunk sometimes reaches a circumference of 30 m. This immense girth and stiff branching give the impression of a bottle full of twigs. A spongy mass of parenchymous tissues fills the thick trunk, which typically becomes saturated with water and is often hollow. The smooth, metallic-gray bark has a remarkable ability to heal any wounds. Roots extend far from the base of the tree and probably account for the dearth of nearby vegetation. There may be a taproot as well, though reportedly not deep.

The leaves are compound and digitate, usually with 6-8 oblanceolate leaflets. The common stalk is usually about 8-15 cm long and the individual leaflets lack stalks. Whether in full leaf, in flower, or in fruit, it is one of the most beautiful and fascinating of trees. Whole plantings can become bespangled with white blossoms that attract bats, giving rise to masses of fruits hanging on long stems like ornaments.

Distribution

Within Africa This species is found throughout tropical Africa, but especially in the sub-humid regions and the semi-arid zone to the south of Sahara. Its northern limit (in Senegal) is about 16°N; its southern limit is about 15°S in Angola to 22°S in Botswana and to 24°C in Mozambique (at Chokwe). The species is also a famous feature of the Madagascar landscape, but *Adansonia digitata* seems not to be native there, the homeland of the genus. It perhaps arrived with Arab traders who carried the seed out of Africa centuries ago.

Beyond Africa Baobabs have long been planted in locations throughout the tropics, and have been introduced into the Americas and Asia. Its widespread occurrence in India, Sri Lanka, and elsewhere around the Indian Ocean is due to Arab traders who carried the seed out of Africa centuries ago. It is also well known in the far north of Australia, and is scattered as an ornamental through much of the tropics.

Horticultural Varieties

No formal varieties have been recorded for vegetable use. However, in the Sahel four baobab types are loosely recognized: black-, red-, and gray-bark, and dark-leaf. Dark-leaf baobab is preferred for use as a leafy vegetable, while the black- and red-bark baobabs for their fruits.

Cultivation Conditions

Generally, baobabs occur in semiarid to subhumid tropical zones. These light-demanding trees do not like the dense tropical forests.

Rainfall Baobabs are most common where mean annual rainfall is 200-1,200 mm. However, they are also found in locations with as little as 90 mm or as much as 2,000 mm mean annual rainfall.

Altitude The tree can be found from sea level to 1,500 m (notably in eastern Africa), but mostly occurs below 600 m.

Low Temperature Baobab is said to thrive where mean annual temperature is 20-30°C. It succumbs to frost. Reportedly, germination is achieved only when soil temperature exceeds 28°C.

High Temperature No limits within Africa. It is adapted to at least 42°C (measured in the shade).

Soil Grows on many different soils but develops best on calcareous substrates and on deep, slightly moist sites. Does not tolerate seasonally inundated depressions with heavy clay soils. Despite this intolerance to waterlogging, it thrives along the banks of rivers such as the Niger. Reportedly tolerates laterite as well as relatively alkaline (e.g. limestone) soils. For reasons not explained, it apparently performs poorly in the sandy “millet” soils of the Sahelian zone.

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CELOSIA

Of all the world's vegetable crops celosia is far and away the prettiest. Deriving from the Greek word 'kelos,' meaning burned; the name itself refers to the plant's brilliant appearance and striking flame-like flowers. In a hundred nations the showy heads of this species[1] seem to outshine the sun in gardens, window boxes, streetside displays, and floral exhibits. Not only are the flowers richly hued, their deep-green foliage may also be shot through with streaks of red or purple pigment. As a result, celosia can be eye catching even before it blossoms.

But although this plant catches eyes almost everywhere on earth, few of its admirers know that it is edible, let alone that it is an important leafy vegetable in parts of tropical Africa. In Nigeria, Benin, and Congo, to name just three countries, the fresh young leaves are a common item of diet. They are primarily eaten in a dish prepared from various vegetable greens, combined with onion, eggplant, hot peppers, palm oil (or other vegetable oil), and fish or meat. Sometimes, peanut butter is also added as a thickener. All the ingredients are added to one pot, and brought to a steady boil to produce a tasty and nutritious "soup."[2]

To such dishes celosia leaves certainly contribute their share of nutrients, including calcium, phosphorus, iron, and vitamins, as well as not a little protein. Among people in the know, these dark-green leaves are valued especially for physical (and, at least according to rumor, sexual) stamina.[3]

This intensively cultivated leafy vegetable usually grows about a meter tall but can tower well over 2 m.[4] Two types predominate: One bears

[1] There are 60 *Celosia* species but this chapter refers mainly to *Celosia argentea*, the only one widely planted as an ornamental and food crop. A commonly seen synonym (applied selectively to one monstrously distorted form) is *Celosia cristata*. Another is *Celosia trigyna*.

[2] Information from Haroun Hallack.

[3] "Sokoyokoto," the plant's name in southern Nigeria's Yoruba language, literally means "the vegetable that makes your husband's face rosy," which we think is a wry—maybe sly—joke shared among women in the marketplace.

[4] The plant is a member of the Amaranth family and shares many features with members of the genus *Amaranthus*, such as broad edible leaves with high protein content and

brightly colored flower heads that look like soft, fluffy plumes and remind the observer of crimson, scarlet, or gold feathers. The other is a grotesque genetic anomaly whose flowers are crammed together into wavy lines. These massively wrinkled yellow, orange, crimson, or pink crests often resemble cock's combs. Other variants look like some bright brain coral that inadvertently crawled up out of its habitat beneath the tropical seas.

Because of its flavor, food value, and familiarity, the crop is widely consumed in several parts of Africa. It is, however, of greatest importance in Nigeria and nearby countries. The leaves, young stems, and young flower spikes are handled like spinach. They go into soups and stews, and are served as a nutty-flavored side dish with meat or fish or more commonly with a cereal-based main course such as maize porridge. In some places the leaves are finely chopped and sprinkled into the cooking pot. The flavor is reportedly pleasant, mild, and entirely lacking the bitterness that sometimes spoils other leafy vegetables. The nutritional value is roughly like that of other leafy vegetables.

Despite its African origin (a claim that is not without dispute), celosia is known as a foodstuff in Indonesia and India. Moreover, in the future it might become more widely eaten, especially in the hot and malnourished regions of the equatorial zone. In that regard, it has already been hailed as the often-wished-for vegetable that "grows like a weed without demanding all the tender loving care that other vegetables seem to need."[5]

Because of its wide tolerance to both tropical and dry conditions and because it is usually unaffected by pests, diseases, or soil type, it is among the most promising greens for harsh or fickle growing conditions. The plants spring up with surprising vigor from each tiny seed. They have especial promise for cultivation near millions of huts and hovels, whose occupants can then both enjoy these flamboyant floral accessories and also pluck off some leaves each day and drop them into the soup pot. However, it should be noted that to yield well they need fertile soil.

For subsistence production these supremely self-reliant and uncomplicated resources seem ideally suited. The ornamental form is already spread worldwide and is often to be seen growing, uncultivated and happy as a weed. They propagate easily, require little care, and often reseed themselves year after year. Kaphikautesi, a name used for this plant in

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flowers and seeds produced in dense spikes. Nonetheless, *Celosia* is a separate genus and differs in having the normal C3 photosynthetic pathway rather than the unusual C4 cycle that endows drought tolerance on amaranths. This present chapter should be read in concert with the first chapter, which details issues written with leaf amaranths in mind but that also relate to celosia, which appears to be a good alternative leaf vegetable to local amaranths where they might tend to be susceptible to insect pests.

[5] "Every place I have tried it," writes Martin Price of Florida, "it grows with no work. We have had no disease problems and very little insect damage. It reseeds itself abundantly and new plants have come up in the immediate vicinity."

Perhaps the prettiest of all vegetable crops, celosia is used as an ornamental almost everywhere on earth. But few of its millions of admirers know that it is a common item of diet in parts of tropical Africa, where it is native. The fresh young leaves, young stems and young flower spikes are used to produce a tasty and nutritious "soup" that is a daily fare especially in West Africa. Productive and simple to grow, the plant could in the future become a much greater contributor to African welfare, especially to the hot and poorly nourished regions of the equatorial zone. (Bud Markhart)

Malawi, means "eaten by lazy ones," a recognition that not only are the plants easy to produce but that they cook quickly and with little fuss or fuel.

PROSPECTS

Celosia seems a promising green for use in the hot humid tropics, especially during the rainy season. It can be very high yielding and its young leaves have a good taste and a good nutritional value. Cheap, simple, productive, heartwarming, this crop lifts life, not only perking up the surroundings with its flowers but perking up the consumers with a healthy, nourishing food. It is an excellent vegetable type to be promoted, at least in West and Central Africa where it is already known.

Within Africa

Humid Areas Excellent. Celosia is grown throughout West Africa's warmer and wetter sections. It is, for instance, Southern Nigeria's most important leaf vegetable and is raised in myriad home gardens and farm plots, both for family and the local market. Humidity and heavy rainfall fail to limit growth, so celosia is commonly cultivated during the wet season when other crops succumb to molds, mildews, and like maladies.

Dry Areas Modest. For maximum development the plants normally require at least moderate soil moisture. Although they survive dry periods, without irrigation the level of leaf production is likely to be uneconomic in parched climes.

Upland Areas Excellent. The plant is well known in East Africa's highlands under its Swahili name, mfungu.

Beyond Africa

Throughout the world's temperate regions people enjoy this easy-to-grow short-lived (ornamental) annual during the summer months. Few, however, know that celosia is a warm-weather spinach substitute. They plant it for show rather than soup. Celosia is also eaten in India—although one report notes that it is eaten "in times of scarcity." So maybe it lacks cachet as a food there as well.

USES

Generally, celosia is used like leaf amaranth (see Chapter 1).

Leaves As already stated, the leaves—not to mention young stems and young inflorescences—are eaten as potherbs. They soften up readily and cook in just minutes. The texture is soft; the flavor very mild and spinach-like. These boiled greens are often added to stews. They are also pepped up with such things as garlic, hot pepper, fresh lime, and red palm oil and eaten as a side dish.

Forage At least occasionally the plants are chopped and used as feed for chickens. The literature also reports them being employed as forage for cattle. The foliage is, however, thought to accumulate oxalate.

Ornamental Uses African families plant celosia as a vegetable not as an ornamental, but let a few plants grow to flowering to get seed. Its use as an ornamental is hardly known in Africa, but it could be. Elsewhere in the world, this is among the most popular choices for bedding and border plants, tall backgrounds, edging, and pot and container production. The blossoms also make ideal cut flowers. In addition, they are easy to dry, being merely hung upside down in a dark, dry place for several weeks. In this form they retain their form and color and can be incorporated into dry bouquets and everlasting flower arrangements. One type, known as woolflower,[6] is especially notable, producing elegant, chaffy flower spikes that glisten even when dry as dust.

Striga Suppression The celosia plant is believed to repress striga, a parasitic weed that devastates sorghum, millet, and maize across Africa. This weed, which engenders both hunger and poverty, thrives where soils are infertile and crops ill-nourished, so it targets the poor most. Whether celosia can help farmers fight back is far from clear, but it is widely called “striga chaser” owing to a reputation for sending the weed on its way. There is not complete confirmation of such ability, but one study found that celosia stimulated striga germination and lowered overall levels 50% while increasing sorghum yields.[7]

Medicinal Uses Various medicinal benefits are widely claimed, including treatments for intestinal worms (particularly tapeworm), blood diseases, mouth sores, eye problems, chest complaints (seeds), and diarrhea (flowers). The leaves are employed as dressings for boils and sores, and the boiled vegetables are said to be slightly diuretic.

NUTRITION

Celosia’s nutritional value is more-or-less comparable to that of other dark-green leaves, but it shows a large variation between samples depending on species/cultivar, soil fertility (more fertilizer means higher content of minerals, provitamin A, vitamin C), harvest stage, and moisture content.

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[6] Sometimes listed as *Celosia trigyna*, a name currently considered a synonym for *Celosia argentea*, the species of this chapter.

[7] Olupot, J.R., D.S.O. Osiru, J. Oryokot, and B. Gebrekidan. 2003. The effectiveness of *Celosia argentea* (Striga “chaser”) to control *Striga* on sorghum in Uganda. *Crop Protection* 22:463-468.

Although many samples have been analyzed in Nigeria, few of the details have been published. Nonetheless, the leaves are believed to contain considerable protein and calcium as well as reasonable amounts of phosphorus and iron (which can be said for many dark-green leafy vegetables). They are also said to be good sources for vitamins A and C, although little tangible evidence for this has been presented so far. A standard analysis, several decades old, lists the following constituents (measured per 100 g edible leaf portion): water 84 g, calories 44, protein 4.7 g, fat 0.7 g, carbohydrate 8 g, fiber 1.8 g, calcium 260 mg, phosphorus 43 mg, and iron 7.8 mg.[8]

Speaking generally, the nutritional value is comparable to that of amaranth (see Chapter 1), although celosia leaves tend to contain a little more moisture.

HORTICULTURE

The plants are propagated from seed, which is normally merely broadcast on top of the soil. A temporary covering of dry grass helps protect the tiny and very vulnerable seeds from washing away under heavy rain and runoff. Once they've germinated and set down roots (after about a week in other words) the grass covering is removed.

The seeds may also be planted directly into the soil (they must be placed at a shallow depth, 0.75 cm having been suggested). Moreover, vegetable plots can be established using seedlings transplanted from a nursery when 5-10 cm tall. For best results, it has been recommended that seedbeds be well manured and kept moist. There is nothing difficult about any of this, but weeds are a concern; the young seedlings are easily smothered.

Although relatively pest-free in most regions, the roots are susceptible to nematode infection. In Nigeria the flower stalks and upper leaves are also damaged by something called "leaf-curl." Also in Nigeria the variegated locust attacks immature seed capsules and a beetle feeds on green capsules causing seed loss.

As for diseases, these usually present no problem, but a fungus producing white pustules on leaf undersides seriously damages celosia grown in Nigeria. It is recommended that the infected plants be destroyed to reduce the possibility of infecting subsequent plantings.

HARVESTING AND HANDLING

Typically, the farmer waits about a month or six weeks after sowing her plants before thinning the plot. The tallest plants (usually about 15 cm high) are removed until those remaining are about 25-30 cm apart. The excised

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[8] FAO. 1968. *Food Composition Tables for Use in Africa*. FAO and U.S. Department of Health, Education, and Welfare, Bethesda, Md.

plants go into the cooking pot and represent the first of a series of harvests. As the remaining plants grow taller, the new leaves and terminal shoots are removed as they appear. This provides successive harvests every week or two until the plants get to be about 45 cm in height, a point where they turn stringy and run to seed. The harvest season typically extends for 3-5 months during the rainy season, and longer if irrigation is available.

Large leaves from young plants are best for eating, but young stems and young flower stalks may also be harvested as potherbs.

In Nigeria the quantity of leaf harvested from a 5m^2 experimental plot has been measured. The green form of celosia yielded 8 kg of leaf (the equivalent of 16 tons per hectare). The red form produced 14 kg (28 tons per hectare).[9]

LIMITATIONS

Although tough and resilient, celosia can, as mentioned, be victimized by nematodes. In this regard, a mulch that insulates and keeps the soil cool should be helpful. The plant also succumbs to water-logging or freezing temperatures.

On its face, celosia could become a weed…the world's prettiest. However, even though it already flourishes in most countries, there is little sign of it becoming a curse. Perhaps that's because it is enjoyed not only by every passing goat, pig, or cow but by people as well.

When the leaves are boiled, much of the pigment dissolves, turning the cooking water dark, ugly, and unappetizing. Nevertheless, when the leaves are fished out they retain their pleasant green color. The black cooking water that remains should be discarded because it likely contains dissolved nitrates and oxalates.

NEXT STEPS

This crop needs exploratory investigations and documentation. Country reports from Nigeria, Benin, Cameroon, Congo, and other celosia-eating nations would provide valuable baseline data on botany, plant physiology, and growing requirements, as would collation of worldwide experience.[10]

In addition, this productive, hardy, and attractive plant merits trials in many more areas. Such trials are likely to attract a lot of attention and spearhead the diversification of food crops in new places.

Nutrition The nutritive qualities need to be pinned down. Although details are sketchy, the leaves are rich in protein (almost 30 percent of the

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[9] Tindall, H.D. 1983. *Vegetables in the Tropics*. Avi, Westport, Connecticut.

[10] These might best be circulated via the Internet, because published versions of such reports typically take years to emerge and end up accessible mainly to professionals and already out of date.

dry matter), calcium, phosphorus, iron, and provitamin A and vitamin C. Not only does this need confirmation, but the presence and effects of possible antinutritional factors or toxins should be determined.

Food Technology Now is the time to fill in basic data on celosia quality, cooking, and consumption. It could engage the gamut of food science, including storage, handling, cooking trials, and use of leaves in foods.

Horticultural Development Wherever vegetable-research programs occur, celosia should be entered into trials and research activities. Myriad questions and uncertainties remain to be fully answered, especially optimal ways to cultivate the crop for food production.

Striga Chaser Knocking back this parasitic plant would, by itself, boost the production of food in Africa. Outsiders can hardly imagine the deadening dismay of seeing striga breaking out in your fields. A farmer noticing the pink flowers spreading through the maize or millet crop can do nothing but resign to suffer. Those little blossoms mean more work, less income, more hunger. The family may pull some out, but the damage began long before those flowers appeared. Even rotating the crops or applying fertilizers does little to stop the weed's spread. Moreover, each striga plant yields thousands of seeds, which means that the farmer's crops will be stunted for years to come. As we have indicated, there is no formal confirmation of celosia's reputation as a "striga chaser" and now is the moment to rectify that.

SPECIES INFORMATION

Botanical Name *Celosia argentea* L.

Synonyms *Celosia plumosa* (plume type)

Family Amaranthaceae

Common Names

English: celosia, cock's comb, quail grass, woolflower
French: célosie, crete de coq
Nigeria: sokoyokoto, soko, aodoyokoto
Spanish: mirabel
Sudan: bambit (Kord), el bueida (Ar), danab el kelb, sheiba (Ar)
Swahili: mfungu (Swa)
Yoruba: shoko, yoko
Malawi: kaphikaulesi, chinkanya (Ch), ndangale (Ch), munsungwe (To), nyasungwi (T), chala cha nkhwale (Nsanje name for red kind), nsanzazywale (Nsanje name for green kind).

Zimbabwe: mundawarara (C), isihlabe (Nd), sunku (To)
Zambia: kapiko, lukuli, kalume, kapikolesi
Kenya, *Tanzania*: mfungu (Swa)
Benin: Avounvo
Uganda: ekaliyo (Kmj)
Ethiopia: belbila (Am/T), birsir, shilobai (T)

Description

Celosia is an erect annual herb, normally about 1 m in height but sometimes much taller. The green type—the one most commonly used for food—has few branches, at least until it approaches the time for flowering. The leaves are alternate, light green, and not unlike amaranth leaves to look at. They are typically 2 x 6cm, although those on flowering shoots are slightly longer. Even the green foliage may contain large amounts of betalain pigments.

The often brilliantly colored flowers are borne in dense heads. Most occur in spikes, and stand like spears in the garden bed. But certain cultivated forms have compact or feathery clusters due to fasciation, the accumulation of genetic malformations that are of huge interest to botanists. Gardeners, in other words, love these freaks of nature.

Celosia flowers yield large numbers of seeds that are about 1 mm in diameter and are normally black.

Distribution

Although the plant is known worldwide, its use for food is geographically much more limited.

Within Africa The plant is common in West Africa, from at least Sierra Leone to Nigeria. It is also known in Ethiopia, Somalia, Kenya, and other parts of East Africa. In Central Africa it is found in quantity in Congo as well as probably most surrounding nations. *Celosia argentea* is an important cultivated vegetable in the rainforest zone of Nigeria, Benin, and (much less) Cameroon, Gabon, Togo. The wild form (sometimes referred to as *Celosia trigyna*) is a potherb throughout the savanna area of tropical Africa.

Beyond Africa According to old reports, the leaves have been used as spinach in at least Sri Lanka, Yemen, Indonesia, and the West Indies. They don't seem to have caught on widely, though.

Horticultural Varieties

In terms of celosia as a food crop, there are few horticultural varieties as such. However, in West Africa (especially Nigeria) two distinct forms are recognized. Green soko is erect and up to 150 cm tall. Red soko, on the other

hand, is taller (generally reaching 180 cm) and more spreading and its leaves have a distinct purple marking. Although leaves from both forms are equally good to eat, the green-leafed type is more popular as a food crop.

Environmental Requirements

The exact environmental requirements are unknown, but that hardly limits the crop because it is adaptable enough to perform well under diverse climates.

Photoperiod At least the West African vegetable species (*Celosia argentea*) is a short-day plant. And it needs high light intensity to maintain regular leaf development. Flowers rarely form in seasons and locations with long days.

Rainfall Generally more than 600 mm. Heavy rainfall will not limit growth but the plant can be sensitive to drought.

Altitude Grows well in low altitudes; but occurs up to 1,700 m in Ethiopia and occasionally up to 1,500 m in the Himalayas.

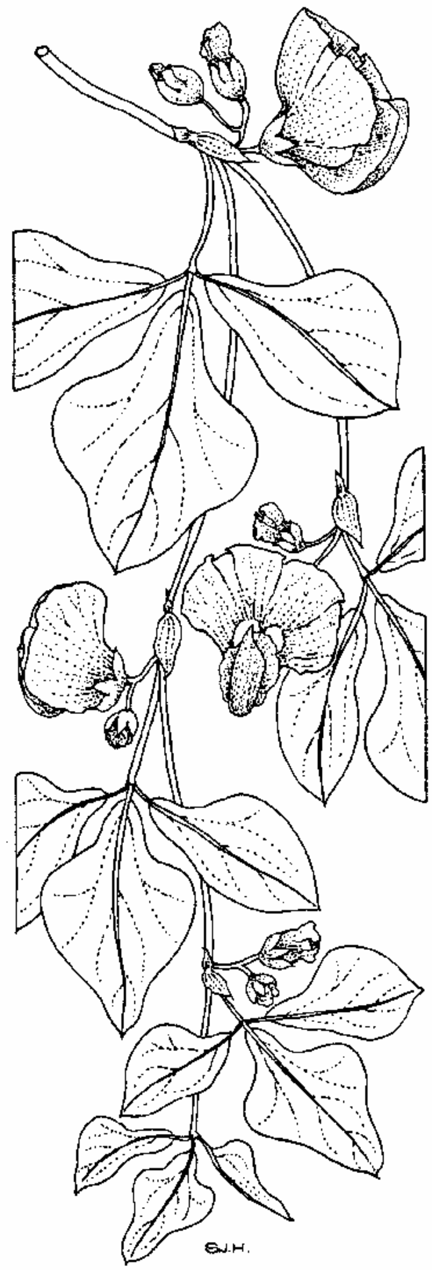
Low Temperature Must be planted when all danger of frost has passed.

High Temperature A stable high temperature of 20-25°C is suitable for both edible varieties. But celosia does quite well in Florida's cool winter as well as its hot summer.[11]

Soil Celosia tolerates many different soil conditions, although high levels of organic matter encourages good yields and reduces damage from rootknot nematodes

[11] Information from Martin Price.


REPUBLIQUE POPULAIRE DU CONGO
CELOSIA CRISTATA
2F
FLORE TROPICALE



Vigna unguiculata

5

COWPEA

Considering all the protein sources that might possibly help Africa's malnourished millions, none seems more promising or more practical than grain legumes. Legume seeds famously deliver the amino acids needed to grow or repair protein-based tissues such as brain, nerve, and muscle, as well as to construct the enzymes and proteinaceous hormones necessary for normal life functions. As tools for balancing nutrition they can have a powerful overall effect among the impoverished masses. By providing protein (not to mention vitamins, minerals, and energy), they make main foods—notably, the bulky staples, such as rice, maize, cassava—work better in the body. In this sense, they help increase the bioavailability of other nutrients. Grain legumes, in other words, act like nutritional cogwheels, making everything else go round and round in proper order.

Luckily for the particular malnourished millions in Africa there are grain legumes for almost every local soil and climatic zone.[1] In the specific areas most at risk of hunger and malnutrition, though, the leading locally domesticated candidate is cowpea. Although hardly known in global terms, cowpea constitutes Subsaharan Africa's most widely planted native legume. At present it is the second most important grain legume continent-wide; only peanut—a native of the Americas—occupies more African farmland. West Africa's farmers alone grow cowpea on an estimated 6 million hectares. More than 95 percent of the world crop comes from that area; Nigeria, the biggest producer, grows an amount variously estimated at several million tons a year.

Given quantities like that, one might question this species' inclusion in a "lost crops" book. But the cowpea's widespread occurrence and importance in the lives of the most malnourished makes this particular grain legume critical for lifting the nutritional baseline for many societies and many levels of those societies. In a sense, it is a fulcrum for leveraging Africa's basic nutrition. For all that, though, it is now not being intensively used to leverage the continental wellbeing. In this special sense, then, cowpea is being "lost," at least to future progress.

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[1] These include peas, beans, peanut, soybean, chickpea and similar grams, lentil, and faba bean.

Although globally obscure, cowpea is grown by tens of millions of smallholders in Africa. In fact, it is estimated that 200 million children, women, and men live off the plant—consuming the seeds daily whenever available. Widely appreciated by the poor, cowpea seed is not only rich in protein but in oil and digestible carbohydrate too. (The Burpee Seed Company)

Regarded strictly from a botanical perspective, this crop seems strong enough to help lift Africa's food quality in the 21st century. The species is exceptionally rich in useful genetic diversity. It produces several different tasty foods. The plant is deep rooted, vigorous in growth, and reliable in production. It is both drought-tolerant and adapted to poor soils. The seeds are exceptionally nutritious, possessing protein (up to 24 percent in dry seeds) and a trove of other essential nutrients. As a dietary component, it complements the otherwise unbalanced diets the poorest sectors are forced to stomach. And, perhaps because of its African birth it beats out other legumes for performance on a variety of soils and an adversity of conditions found across this multiform continent. Indeed, cowpea has been called "a nearly perfect match for the African soil, weather, and people."

This crop originated as an inconspicuous little creeper among the rocks of the dusty southern Sahel and the bone-dry upper rim of central Africa. Africans living there thousands of years ago saved the best seeds they could

find and ultimately brought cowpea entirely under their care. Today, interpollinated descendants of their creations grow on millions of smallholder farms in a sweeping arc from Senegal eastward to Sudan and Somalia and southward to Zimbabwe, Botswana, and Mozambique.

In that great sweep, covering half of Subsaharan Africa, two hundred million children, women, and men live off the plant—consuming the grain daily whenever supplies make that possible. Widely appreciated by the poor, cowpea is not only rich in protein but in digestible carbohydrate too. Its energy content nearly equals that of cereal grains. In addition, the seed is low in antinutritional factors. And the seeds of select strains cook fast, an important consideration where fuelwood is scarce and expensive, as it is in that vast parched crescent of concern between Senegal and Mozambique.

One of the more remarkable and valuable things about this species is that certain of its cultivars mature with as little as 300 mm of rainfall. This makes it the grain legume of choice for the Sahelian zone and its contiguous savannas, both of which are population-dense, hungry, and vulnerable to outbreaks of malnutrition and mass misery.

No less remarkable is cowpea's value to the environment. The deep roots help stabilize the soil and the plant's shade and dense cover helps protect the ground and preserve moisture. Both these traits are of particular importance in the dry zones, where moisture is at a premium, soil is fragile, and wind a dirt-scouring demon. Like other legumes, cowpea fixes atmospheric nitrogen, thus lifting the nitrogen content in the land around it. It is often intercropped with sorghum, millet, or maize, as much to foster their good health as to furnish its own beans.

Beyond its value to the malnourished, this is a crop of high potential for rural development. Although Nigeria produces it by the millions of tons, production in East, Central and Southern Africa is still very low.

PROSPECTS

Because of its combination of benefits, cowpea is perhaps the most vital of all Africa's native vegetables. It seems thus likely that it has the best potential for boosting the nutrition of the greatest number of needful Africans. Even a small lift in cowpea performance can have a significant spillover benefiting millions[2] .

Within Africa

Humid Areas Prospects here seem moderate, but could rise quickly. In wet areas, cowpea falls victim to hosts of pests and diseases. Nonetheless,

[2] Such an initiative was begun by the long-standing USAID-funded Bean/Cowpea Collaborative Research Support Program, focused on research and training of scientists from Africa, Latin America, and the U.S. Information is available at isp.msu.edu/crsp.

types that flourish in moist savannas are coming available, and those could provide a solid foundation to build a better future.

Dry Areas Excellent. Cowpeas are more drought-tolerant than peanut or maize (but not more than millet), and are vitally important in the West African savanna, where the bulk of the crop is produced.

Upland Areas Variable, depending on location, but no less promising for all that. Most cowpea varieties do not withstand cold conditions that well. They either fail to germinate, grow slowly, or do not flower at all. Production in the highlands during hot, dry seasons can be very high however.

Beyond Africa

The dried seeds are eaten in parts of the Asian and American tropics and subtropics. They are, for example, well known in India, Brazil, the Caribbean, and United States, known there as blackeye peas. As better cultivars come available, cowpeas could become even more important in the dryland tropics. According to reports, cowpea is taking off in Thailand. China and a number of other nations seem ideal targets for future expansion. There, cowpea could contribute inexpensive protein to many predominantly starchy diets.

USES

Unlike other legumes, cowpea can be consumed at different stages in its development: fresh green leaves, dry leaves, green pods, green beans, or dry grain. The most popular—or at least most common—is the last.

Pods The immature seeds and the immature seed pods are boiled and eaten as a vegetable. This is a very special and highly promising usage. Indeed, we have dedicated a separate chapter to a cowpea variant called long bean, which developed far from Africa's shores and now deserves better back home.

Seeds Traditional West African cooking has found a variety of uses for this food. There, most cowpeas are cooked with vegetables, spices, and palm oil to produce a thick soup that accompanies the basic staple, notably cassava, yam, or plantain. The seeds are also decorticated, ground into a flour, mixed with chopped onion and spices, and pressed into cakes that are either deep-fried (akara balls) or steamed (moin-moin). Some are ground or crushed into meal that is used in buns, fritters, and sauces. Cowpea meal is also boiled, mashed, and served in puddings, porridges, and soups. The seeds are commonly boiled with maize, eaten as porridge, or even boiled in

their pods. Alternatively they may be steamed or fried to make a paste or sauce that is often eaten with ugali or other thick starchy staple. Canned cowpea has rapidly become popular in the Zimbabwean markets.

Forage In most locations cowpea is treated as a dual-purpose crop, in which one of the two products is hay. In years of poor rainfall, when stockfeed is scarce, it can be worth far more than the seeds. Livestock, particularly cattle, thrive on the stems and leaves left once the seeds have been harvested. Those haulms can also be dried, bundled, and stored away for the dry months when little else is around to keep domestic creatures happy and healthy.

Green Manure Cowpea fixes nitrogen efficiently, with amounts of up to 70 kilograms per hectare per year added to the soil. This makes it a useful living mulch for reconstructing broken-down land.

Other Uses Occasionally, cowpeas are roasted, ground, and served as a coffee substitute. In the United States, the green seeds are sometimes roasted to produce peanut-like snack foods.

NUTRITION

Dried cowpea seed is exceptionally nutritious, with up to 24-percent protein and 2 percent oil, with the remainder being carbohydrate, minerals, and lesser nutrients. This combination means that cowpea packs solid nutrition. On top of that it is palatable and relatively free of the kind of metabolites that suppress soybean’s food value.

The protein itself is of good nutritional quality, consisting of 90 percent water-insoluble globulins and 10 percent water-soluble albumins. There is considerable genetic variation in amino-acid content, but lysine seems always in good supply. Indeed, that is one of the greatest features: combined with cereals in the diet, cowpea makes up for the lysine-poor cereals and roots. As in other grain legumes, methionine, cystine and tryptophan are deficient.

HORTICULTURE

Most of the crop is grown for home consumption. A portion comes from kitchen gardens or village compounds, but most cowpeas are grown in the main production fields as an intercrop with cereals and/or other crops such as tomato, okra, peppers, and eggplant.[3] In both dry- and moist savannas the cereal is millet, sorghum, or maize. This combination of legume and cereal

[3] Many men grow cowpea too. But most of them grow it as a sole crop and the grain they produce is more likely to be sold than consumed by the family. In this chapter we focus more on the subsistence production, whose growers are mainly women.

makes for a complex, dynamic, hard-to-manage system, but it meets the critical needs of growers, who above all must produce the family's yearlong subsistence. When the first rains appear, they typically plant the cereal together with an early-maturing cowpea (which is often destined for fodder rather than food). Once the cereal is growing well, a second cowpea crop is sown among the strengthening stems—a strategy used notably in the drier areas to avoid early season drought damage. Clambering types are considered best because they climb over and crush any weeds that try to interfere. Once the creeping cowpeas start moving out weeds are no worry.

Traditional cowpea types in the Sahel and savannas are attuned to subtle differences in the length of day. As if reading a calendar, they burst into flower just as the rainy season ends and the long period of dryness begins. That is a clever way to avoid devastation from pests and diseases, because vulnerable parts of the plant emerge after enemies have subsided. It is, however, a risky strategy because it puts the plants at the mercy of drought and blistering heat. Also, in this seemingly synergistic cultivation system, the crops compete for each other's light, nutrients, and moisture, which limits the capabilities of both. It the rains disappear too quickly, as occurs too often, the competition between cereal and cowpea can have catastrophic consequences on the quantity of food the family gets to eat that year.[4]

HARVESTING AND HANDLING

Depending on cultivar and climate, cowpeas may take as few as 60 or as many as 240 days to mature their seeds. Harvesting is complicated by the prolonged and uneven ripening characterizing many types. The pods must be harvested as soon as they mature because they shatter easily and after a few days wantonly scatter the seeds on the ground. Further, seeds that get damp from rain or excessive humidity before being harvested start sprouting inside the pods while yet on the plants.

LIMITATIONS

Under conditions of subsistence agriculture, the average yield of dry seed normally ranges between 100 and 300 kg per hectare. Compared to yields of modern soybean (3,000 kg per hectare and up), peanut (2,000), or even cowpea grown on experiment stations and in countries such as India (at least 2,000), this is an appalling level Much of the difference is due to the fact that cowpea occupies only a small part of each hectare of the mixed cropping system. But some is due to the particular types used by Africa's subsistence farmers. Those traditionally selected plants may be very clever at dodging their enemies but from a productivity standpoint, they aren't very good.

[4] Over the past decades, there has been a steady decline in annual rainfall throughout the region. Therefore, growing two crops together increasingly requires compatible cultivars, more and more tolerant to drought.

Whatever the climate, locale, or cultivation method, insects are the major constraint. In the lowland tropics the effect can be so devastating that overcoming them could send grain production soaring 20 fold or more, according to literature reports. But it is not an easy task. Africa has at least 15 major and more than 100 minor insect pests that challenge cowpea.

By comparison with the insect onslaught, diseases are less troublesome, but that's not saying much. Fungi sometimes cause terrible damage, especially in the wetter areas. Devastating attacks are not unknown in the drier areas as well.

Even when the harvest is in hand, the farmer's fight for her food is far from over. Certain insects make their living on cowpeas in storage. Cowpea weevil and bruchid beetle are the major threat here. They begin infesting the plant in the field, but really capitalize when the seeds are crammed together in a grain bin or silo. There in weevil heaven each female produces 20 ravenous larvae every 3 or 4 weeks, so within a few months nearly every seed has a neat hole drilled in its side. And within six months little that is edible remains. Food prepared with even partially infested grain tastes bad, and selling seed exhibiting even a few of the telltale beetle holes is difficult. In Nigeria it has been estimated that some 30,000 tons of cowpea grain are lost annually, most of it during storage.

NEXT STEPS

Perhaps the quickest way to get cowpeas in Africa producing up to their fullest potential is to activate programs in Asia and the Americas. A global effort, involving say 20 nations from China to Chile and Australia to Arabia, could change the whole dynamic. This is not such an unlikely notion. Almost all nations face a long-term need for more drought-tolerant and more nutritious crops. In fact, cowpea is already rising slowly as a global resource. From this worldwide movement, the humanitarian benefit to the continent that produced the plant in the first place could be the greatest of all. But by developing new methods of production, new gene combinations, and new basic knowledge, all countries would be benefiting their own farmers and citizenry while building new momentum for a largely forgotten global crop.

So far, the main thrust of research for the cowpea-zone of Africa has been to induce farmers to grow the crop in pure stands rather than mixed with cereals. This is clearly a good thing if one considers only cowpea. But the subsistence farmers depend on the combination, and the switch to a single crop can reduce overall productivity. For small-scale farmers it may also weaken their security by taking away millet or sorghum, their most dependable crops. Nonetheless, for farmers with surplus land and labor, pure-stand cowpea makes an attractive cash crop. Researchers involved in it are not wasting their time. Some observers claim that such commercial production will never benefit enough cowpea growers to justify the research, but they could well be wrong. Cowpea has the potential to be a tool the

millions of impoverished farmers employ to lift themselves from poverty to prosperity. Given a chance to make a good profit they may embrace commercial cowpea with gusto.

Demand for cowpea fodder far exceeds current production, and a ready market exists for cowpea haulms, which can command nearly the same price as cowpea grain. Some emphasis should be put on this usage, even though feeding animals may seem a roundabout means for getting food to people. In this arena, cultivars primarily for fodder or green manure merit exploration.

Commercial Promotion The status of cowpea could be greatly lifted by stimulating demand through a sophisticated marketing campaign. Cowpea lends itself to this. It is a delicious food; it is grown, at least in Africa, organically without chemical inputs; it is a product that supports the poorest of African farmers; and it allows them to make a living from a hostile environment. Such a campaign could be targeted at local, regional, and international consumers (such as in Europe and North America). With bigger markets, research stations will fund more research, the private sector will finance product development, and the farmers of Africa will grow more cowpea and make a better living.

Food Technology The seeds have a relatively high protein content and it has been suggested that this could be extracted to prepare protein concentrates for the food manufacturing, textile and paper industries. In this regard, cowpea might end up Africa's counterpart of Asia's soybean…one of the world's top crops.

Combating the cowpea's enemies in storage is far from easy. Some progress is being made, however. In Nigeria it is recognized that harvesting promptly reduces the initial damage and that storage in the pod affords a degree of protection. Fumigation is effective, but difficult for small farmers to perform efficiently and safely. The hermetic storage of cowpeas in small granaries, silos and pits is being developed in Nigeria, where a very encouraging development has been the use of plastic liners in traditional dried-earth granaries. Investigations in Senegal have shown that cowpeas may be stored satisfactorily for up to a year in plastic sacks, albeit using as a fumigant the very toxic carbon tetrachloride. In India, the leaves of the neem tree are added to bins containing grains such as cowpea. Neem grows well in the cowpea zone of Africa, and this is another likely means for securing safe storage.[5] Cowpeas treated with palm, peanut or coconut oils are reported safe against insect infestation for as long as 6 months, but that affects the taste of some foods, and the seeds may lose their viability. Progress has been made, too, with breeding or selecting plants whose seeds resist bruchids, but

[5] For information on neem, see the companion volume *Neem: A Tree for Solving Global Problems*.

Kano, Nigeria. Cowpea is the grain legume of choice for the Sahelian zone and the contiguous savannas, both of which are densely populated, erratically dry, and vulnerable to mass outbreaks of malnutrition and misery. Its seeds provide quality protein and other essential nutrients that complement the otherwise unbalanced diets that the poorest sectors are forced to stomach. This farmer is growing a dual-purpose cowpea developed by International Institute of Tropical Agriculture and now being widely adopted by farmers as a crop to feed both humans and their animals. (B.B. Singh/IITA)

these seeds tend to be dark and thick-skinned, and that can make people resistant too.

Horticultural Development A dominant factor limiting seed yields is depredation by insects feeding off plants. Thrips are often most important, and these flower-eating scourges are so efficient that often no blossoms remain to form pods. Also slashing yields are pod borers that ream their way inside the pod and consume the soft contents before any seeds mature.

Controlling these pests seems a good topic for the methods and principles of integrated pest management. Already, it is known that destroying all diseased plant material in the field, employing mixed cropping system to reduce pest load, as well as rotating crops, helps lower insect depredations.

Fast-maturing cowpea types minimize the exposure to diseases (not to mention pests and even harsh weather), and are very desirable and important. However, the most effective long-term solution to the disease problems lies in the development of resistant cultivars. Research has already attempted this, but without producing breakthroughs big enough to cause the millions of subsistence farmers to switch.

The process of mixed-stand cultivation has fallen in and out of fashion with researchers in the region since the 1970s, without significant technologies resulting. Yet this is how African farmers grow cowpea, and it is begging for better understanding and support. The field layout is one feature for consideration.[6] The genetics of the plants is another. Farmers committed to the dual-cropping system with cereals and cowpea need daylength sensitive types that produce a flush of flowers after the cereal harvest. Breeding for every latitude and local preference would be a logistical and financial nightmare. But research aimed at improving plants for the main growing regions is well justified.

On a slightly different note, in Guinea cowpeas are being experimented with as a fallow crop in lowland rice fields. Initial results in 1999-2000 were said to be very promising with good yields, high levels of farmer interest, and noted contributions to soil fertility (which were the reasons for initiating the trials). This may introduce cowpea to a completely new, high potential environment, where it can make important contributions.

Storage The problem of insect infestation cannot be over-emphasized. One of our reviewers writes: "In Zimbabwe, we have tremendous difficulties with bruchids and must make sure crop gets from farmer to warehouse where it can be fumigated as soon as possible. It makes on farm storage and factory storage problematic." In this regard, an appropriate technology was developed at Michigan State University in the 1980s. Researchers discovered that simply turning the sack in which beans are stored is enough to virtually eliminate weevil damage. Weevils require upwards of 24 hrs to bore into a grain. During this time they need to brace themselves against neighboring grains in order to drill into their target. Turning the sack end-over-end 2-3 times once a day causes the weevils to loose their place, and require them to start afresh. After several aborted attempts the weevils die without having laid a single egg![7]

SPECIES INFORMATION

Botanical Name *Vigna unguiculata* (L.) Walp.

Synonyms *Vigna sinensis*, *Vigna sesquipedalis*

Family Leguminosae. Subfamily: Papilionoideae (Faboideae)—Pea family

Common Names (for grain types)

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[6] The standardization of row plantings—3 or 4 rows of cowpea to 1 or 2 rows of cereal, for example—has shown promise in trials, but is nowhere being widely applied by farmers.
[7] Information from Brent Simpson.

Arabic: Lupia (in Sudan)
English: cowpea, blackeye pea, blackeye bean, marble pea
French: niébé
Spanish: chicharo de vaca
Ethiopia: adanguari, nori
Nigeria: agwa, akidiani
Uganda: amuli, boo-ngor, omugobe, boo (in Acholi and Luo)
Zambia: ilanda, nyabo (in Tonga language)
Zimbabwe: nyemba (Shona) ndlubu (Ndebele, Zulu)
Botswana: dinawa, Nyeru or Dinawa (in Setswana)
Kenya: boo (in Luo language); kunde (in Swahili); thoroko (in Kikuyu)
Portuguese: ervihia de vaca
India: barbata, charla, Nindu pea, paythenkai, thattapayru (Tamil)
Sri Lanka: me-karak
Malaysia: kachang bol
Philippines: karkala, kibal
Thailand: tonkin pea
Mauritius: voehme (in Mauritian Creole)
Tanzania: kunde (in Swahili); nkunde (in Nyiha)
Lesotho: lLinaoa (in Sesotho)
South Africa: dinawa (in Northern Sotho)
Malawi: nkunde (in Tumbuka); khobwe (in Chewa)
Swaziland: tinhlumayi (in Siswati)
Seychelles: brenm (in Seychellois Creole)
Namibia: omakunde, olunya (white with black eye), omandume or ongoli (mixed black, brown, purple) (in Oshiwambo language, Ovambo tribe)

Description

Cowpeas are an annual crop. There are many different types, varying in growth habit from erect or semi-upright to spreading and climbing. They range in height (or length) from 20 to 200 cm, the latter being the climbing ones. The species is largely self-pollinating, but up to 2 percent outcrossing has been reported.[8] Flowers may be purple, pink, white, blue, or yellow. Pods tend to be long, smooth, cylindrical, and somewhat constricted between the seeds. Between 8 and 20 seeds occur per pod. They are globular to kidney-shaped, 5-12 mm long, smooth or wrinkled, and ranging in color from white, cream, or yellow to red, brown, or black, while some are speckled or blotched. The seeds are characteristic in having a marked white hilum surrounded by a dark ring. The most commonly grown are the white types or those with a black mark around the hilum, the latter being called

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[8] Lush, W.M. 1979. Floral morphology of wild and cultivated cowpeas. *Economic Botany* 33:442-447.

'black-eyed.' Pods of most varieties hang downwards but in some they point sideways or upwards.

Distribution

Within Africa The leading cowpea growing countries are Nigeria and Niger, but the land area planted to the crop is substantial in Senegal, Mauritania, Mali, Burkina Faso, Côte D'Ivoire, Ghana, Benin, Togo, Chad, Cameroon, Central African Republic, Congo, Uganda, Tanzania, Sudan, Ethiopia, Kenya, Angola, Somalia, Zambia, Mozambique, Zimbabwe, Botswana, Namibia, South Africa, and Madagascar. Of total world production, about 80 percent comes from Nigeria, 80 percent of whose harvest comes from the parched northern states of Kano, Sokoto, and Borno.

Beyond Africa Cowpea is an important crop in some tropical American countries, especially in northeastern Brazil. In the USA, where "black eye peas" is a heritage crop, there is considerable cowpea production; California, Texas, Arkansas and the southeastern states yielding 20,000 tons a year. Most production is for the dry grain, but in the southeast it is grown primarily to serve the fresh and frozen market. It is also grown on a limited scale in the Mediterranean region and Australia. In India, the crop is grown especially for the immature pods and beans, fodder, and green manure. Indians enjoy cowpeas either boiled whole or mashed into dhal.

Related Species

Because of the large number of distinct forms and the fact that hybridization is readily achieved, there is much confusion and disagreement on the proper classification of the vast, spreading genepool of the crop called cowpea. All the forms are interfertile, can be crossed freely, and free gene flow is possible, and it now seems widely accepted that there should be no distinction at the species level. In other words, there is a single species *Vigna unguiculata*, with the other names as synonyms (and, often, subspecies). It seems probable that some, if not all, of the cultivated forms are in fact hybrids.

Nonetheless, the vast diversity selected by humans over thousands of years in this species has scarcely been tapped by modern science. There are myriad forms that could provide rewarding work to aspiring plant champions, and great benefits to humanity. One of these, the long bean (subspecies *sesquipedalis*), is highlighted in Chapter 12. A related species of *Vigna* (a genus of about 150 species) is the bambara bean (*V. subterranea*), discussed in Chapter 2.

6

DIKA

Throughout a vast swath of western tropical Africa, from Senegal to Angola, dika is a part of the diet. In the southwestern corner of its range, from Nigeria to Angola, the fruits are eaten. However, in the main area of occurrence, from Senegal to Uganda, the major food by far is the seed. Despite international obscurity, dika is hardly a minor resource. It provides food and income to rural communities in almost twenty countries. In several countries—Cameroon, Nigeria, Gabon, and Equatorial Guinea, for instance—it is one of the most widely sold of all forest products. Millions count on it for cash during the harvest season.

Throughout its native range the tree providing these valued fruits and seeds is among the most appreciated natural resources. When forests are cleared dikas are universally left untouched. Those treasured, multi-branched specimens topped by dense and often curving canopies of foliage are to be seen scattered through many secondary forests.

In season these companionable trees, which can grow as high as 40 m, become laden with green-and-yellow fruits that look like small mangoes. Depending on the species, the fruits vary between sweet and bitter.[1] Although the sweet version is mainly enjoyed fresh, it is also turned into jelly, jam, or "African-mango juice." There's even been an attempt to make dika wine—the result, so its maker claims, being compared in tastings to a Moselle Riesling.[2]

Seen in Africa-wide perspective, however, the fruit is a tiny resource compared to the seed. Each year harvesters gather "dika nuts" by the thousands of tons. The hard round balls, which look something like smooth walnuts, must be cracked open to get to the edible part. The kernels found inside have the texture normal to nuts and can be eaten raw or roasted like

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[1] In recent years the two forms of this versatile plant have been proposed as separate species but acceptance has been incomplete. The "eating type," which yields good fresh fruits, retains the original name *Irvingia gabonensis*. The "cooking type," whose seeds are widely processed across West Africa, is called *Irvingia wombolu*. Harris, D.J. 1996. A revision of the Irvingiaceae in Africa. *Bull. Jard. Bot. Belg.* 65:143-196.

[2] The wine produced after 28 days of fermentation had 8.12 percent alcohol content. Akubor, P.I. 1996. The suitability of African bush mango juice for wine production. *Plant Foods Hum. Nutr.* 49:213-219.

cashews. Most, however, are processed. Some are pounded into dika butter, a product akin to peanut butter or almond paste. Some are compacted into blocks resembling chocolate (once called Gaboon chocolate). Many are pressed to squeeze out the oil that makes up more than half the kernel's weight.

In the main, though, the kernels are ground and combined with spices to form the key ingredient in "ogbono soup." This extremely popular special dish is a sort of unifying regional favorite (although every country fervently considers that it produces *the* best). Like okra and baobab leaves, this so-called dika bread provides the slippery texture so beloved in African soups, stews, and sauces. It also adds a sharp and spicy tang that is unforgettable.

Given the popularity of ogbono[3] soup, dika kernels are traded on both a local and a regional scale. All across western Africa they bring high prices, especially out of season. Even as far back as 1980 it was calculated that a farmer could make US$300 from the seeds gathered off a single dika tree.

Strongly flavored condiments such as dika are crucial to diets where staples are bland in the extreme. Sharp tasting soups, sauces, or stews add both flavor and nutritional balance to cereals, tubers, plantain, fufus, and doughs (cold gelatinous, warm glutinous, and steamed non-glutinous) that anchor the West African diet. Traditionally, these condiments contained local bushmeat, fish, leafy vegetables, dawadawa, dika, spices, or oils. In more recent years, however, foreign ingredients—including tomato, onion, garlic, chili pepper, black pepper, celery, and parsley—have begun making inroads. Even European processed products, including bouillon cubes and dehydrated soup mixes, are nowadays prime ingredients in traditional African sauces. Nonetheless, the original components—including dika, okra, egusi, sesame, spicy cedar, peanuts, oilbean seed, as well as an immense variety of leafy vegetables—still remain in common usage.

That continuing tradition is certainly surprising in the case of dika products, which are gathered individually by hand from scattered wild trees. Throughout history the notion of commercially cultivating this resource and creating an organized industry like that of, say, cashew has been inconceivable. Of the various hindrances, the biggest was the once-widespread belief that dika trees must be at least 10 or 15 years of age before they bear any fruits or nuts. For any large-scale operation requiring financial investment that was a killer condition.

Now, however, pioneers are opening a new future for this crop's wider use. Although still basically a wild species, dika can be said to be in the early stages of domestication. Advances now transforming its prospects include the recent availability of trees selected for kernel qualities such as shells that naturally crack open by themselves (like the commercial pistachio). Perhaps the greatest advance has been developments in

[3] Also spelled agbono. Another widely used common name is apon.

Dika fruits have traditionally been collected from wild trees in the forests, so not much has been reported about their likely ultimate contribution to food security. Nonetheless, harvesters gather dika nuts by the thousands of tons each year, and those kernels, if dried, can be stored for long periods. Through dika, millions of farmers already earn a critical income. They sell the fruit for juice, jam, jellies, and the fresh market. They sell the oil to factories making margarine, soap, or pharmaceuticals. The greatest profit center of all, however, is in the defatted kernel meal. (E.C.M. Fernandes, ecf3@cornell.edu)

vegetative propagation, allowing mass replication of such elite germplasm. Just as important, though, vegetative propagation slashes the delay in fruiting time; budded trees reportedly start producing fruits and seeds just two to four years after planting.

Those advances in knowledge are transforming the possibilities for this formerly scientifically obscure resource. Nigerian researcher J.C. Okafor for more than a decade developed horticultural techniques to facilitate commercial cultivation. In recent years, more and more researchers have begun to follow through with their own investigations. The International Centre for Research in Agroforestry (ICRAF, now the World Agroforestry Centre) chose dika as a priority species for African agroforestry.[4] Already, small experimental plantings have been established in Nigeria: at Iva Valley in Enugu and at Onne in River State. The latter was planted using marcots (air-layering plants), which flowered and fruited just 2-4 years after planting. Both Nigeria and Cameroon have even begun creating village-level nurseries where dika trees designated "superior" by local farmers are vegetatively propagated.

Although vast uncertainties still remain, no insurmountable barriers to this plant's complete domestication are known at this time. The coming years seem likely therefore to bring new life to the production of both nuts and fruits—making an agro-industry that is bigger, better organized, and more reliable than ever in dika history. Possibly, the added output will come from industrial-scale plantations. More likely, it will come from scattered village production as millions of farmers supplement and upgrade the trees they already possess. Dika moreover will be planted for shade, shelterbelts, beautification—along, for instance, streets in cities and highways in the countryside—thereby easing life in more ways than just the provision of food.

These activities are not just emanating from scientists flexing new-won knowledge. Among West and Central Africa's indigenous food plants, dika is high on the list of species the inhabitants hope to see developed. In a survey of five southern Cameroonian villages, for instance, dika was ranked top of the Ten-Most-Wanted-Tree list. Also, a report of farmer preference carried out in southern Nigeria showed that dika was top on the list of 5 preferred fruit trees.

Steamy zones such as southern Cameroon and eastern Nigeria represent one of the dika's special agronomic niches. Tropical lowlands are difficult to farm with modern agronomic approaches, and have consequently fallen behind the rest of the arable world. Dika, however, thrives in places such as the evergreen forests of Gabon, Equatorial Guinea, eastern Nigeria, and

[4] Atangana, A.R., V. Ukafor, P. Anegbeh, E. Asaah, Z. Tchoundjeu, J-M. Fondoun, M. Ndoumbe, and R.R.B. Leakey. 2002. Domestication of *Irvingia gabonensis*: 2. The selection of multiple traits for potential cultivars from Cameroon and Nigeria. *Agroforestry Systems* 55:221-229.

southern Cameroon, where magnificent primeval specimens can still be seen on all sides. This special adaptation to heat and humidity raises the possibility of improved dika plants being employed as an environmentally friendly cash crop for dense, moist, heavily shaded conditions. Communities around Enugu in southeast Nigeria planted dika extensively to control the menace of soil erosion. In the future, it might even help reduce the pressure on the ecosystem that worries so many of today's observers…the African rainforest.

Another important future possibility is the use of dika for lowering malnutrition. Although various oil-rich tropical seeds are being advanced to meet the hungry nations' escalating needs for food energy and protein, few (to our knowledge) are fostering dika for the purpose. Yet the kernel meal is high in oil and protein (including six of eight essential amino acids), and would make an exceptional tool for nutritional intervention in West and Central Africa where marasmus and kwashiorkor are the main baby killers.

Yet a third important possibility is its use as a cash crop. As a reward for hard work nothing succeeds like cash, and in this special regard dika is one of the most motivational of trees. Through it, millions of farmers already earn a critical income. They sell the fruit for juice, jam, jellies, and the fresh market. They sell the oil to factories making margarine, soap, or pharmaceuticals. The greatest profit center of all, however, is in the defatted kernel meal. This shelf-stable soup ingredient even has export potential. Indeed, entrepreneurial West Africans living in the United States already hawk molded ogbono cubes over the Internet.

Considered in overview, then, it can be said that although dika makes up a vital part of the traditional food system in much of West and Central Africa, its full potential has so far gone unharnessed. At this particular moment in history, however, the plant's imminent domestication is opening new opportunities for alleviating rural poverty and malnutrition, while at the same time promoting tree planting, diversifying land-use, and developing durable rainforest agroecosystems capable of superseding today's mindless exploitation.

The current handful of dika researchers are certainly enthused by the prospects their discoveries are unfolding. One calls the exploitation of dika a "win-win landuse strategy for Africa." He envisages a "Really Green Revolution" based on the diversification of agroecosystems with new perennial tree crops that reduce poverty, expand exports, and come close to sustainable agriculture. Dika is not the only species capable of transforming Africa's land use this way, but it is a leading candidate.

PROSPECTS

Given dika's special climatic adaptation and geographical occurrence, the prospects for enhancing its contributions seem good. But they are also limited by the tree's geographic demands.

Throughout a giant triangle from Senegal to Uganda to Angola dika is a part of the daily fare. Although this tree's fruits are eaten in some areas, the seed is the major resource. As a result, this so-far-undomesticated tree scores high on the list of species inhabitants hope to see developed. (Distribution after David Ladipo.)

Within Africa

Humid Areas Good. The real opportunities are in humid West/Central Africa, the area where the species is indigenous. A canopied jungle, however, is not its only habitat. This versatile tree also occurs naturally in gallery forest and semi-deciduous forest, where it stands in the open sunlight. Furthermore, it is often seen—usually standing alone—around the outskirts of towns or villages.

Dry Areas Poor. Dika is apparently restricted to fairly wet, well-drained, loamy-to-clay soils. Probably, it has little potential outside those warm, wet, fertile regions, but no one has tried to find out for sure.

Upland Areas Poor. Although dika seems to have no hope of thriving at altitude, trial plantings of individual trees might prove quite interesting.

Beyond Africa

It seems unlikely that dika will catch on as a food crop outside Africa. Nevertheless, the tree at-the-least would be an interesting one for long-term

plantings such as tropical botanical gardens to acquire and observe. Many now-highly productive trees of the humid tropics—rubber comes to mind—have only hit their stride outside their homelands.

USES

Although various parts of this species have their uses, not excluding the living tree itself, the seed is the resource upon which the crop's future overwhelmingly rests.

Fruits The fruits have traditionally been collected from wild trees for domestic use in the forests of the humid forest zone of southeastern Nigeria, Cameroon, Gabon, and both Congos. Despite the fact that they are routinely consumed in those countries, not much has been reported about their technical qualities.

Seeds If dried, the kernels can be stored for long periods. These dika nuts are usually ground into a smooth paste before use. Typically, that paste is mixed with hot water or slightly heated palm oil to create the unique flavoring that constitutes the essence of ogbono soup. When dropped in just a few minutes before serving, it also serves to thicken soups and stews, producing the viscous consistency consumers covet.

Oil The ground-up meal of dika nuts is commonly pressed to separate the oil. The glycerides in this yellowish liquid are made up largely of saturated fatty acids, notably myristic and lauric. The oil is used, as we've said, in soapmaking and cooking, and it has potential for pharmaceutical use as well.

Wood Dika wood is a local building material. It is a hard, heavy timber with fine grain. It is of minor overall economic value but the trade can be lucrative and exploitive.[5]

Medicinal Uses Dika products are used medicinally in most parts of tropical Africa. In Sierra Leone, for example, the Mende tribe uses the bark to relieve pain. The presence of an analgesic effect has been documented in experiments on mice.[6]

Other Uses The living tree serves as an ornamental as well as a shade tree for food, cash crops, and animals.

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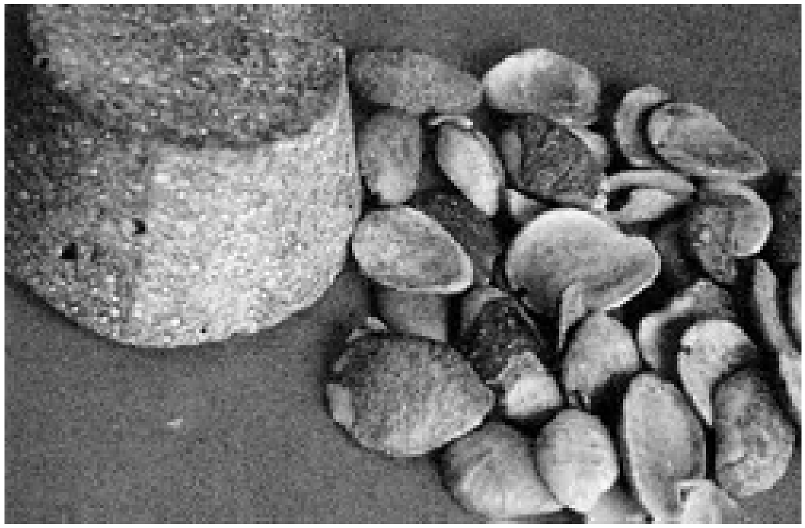
[5] The tree is categorized as "near threatened" on the Red List of Threatened Species maintained by the International Union for the Conservation of Nature (iucnredlist.org).
[6] Okolo, C.O., P.B. Johnson, E.M. Abdurahman, I. Abdu-Aguye, and I.M. Hussaini. 1995. Analgesic effect of *Irvingia gabonensis* stem bark extract. *Journal of Ethnopharmacology* 45(2):125-129.



Dika seed kernels (processed and unprocessed). These so-called "dika nuts," are widely traded in West Africa. They are something like cashews, can be eaten raw or roasted. Most, though, are ground and combined with spices to form the key ingredient in "ogbono soup," a spicy dish extremely popular among West Africans and Central Africans. This shelf-stable soup ingredient even has export potential. Indeed, entrepreneurial West Africans living in the United States are already hawking molded ogbono cubes over the Internet. (R.R.B. Leakey)

NUTRITION

The fruits' popularity is largely due to its sweet-and-sour flavor combination. The sugar content of juice has been found comparable to pineapples and oranges, with even more vitamin C than the latter.[7]

In one set of measurements, the kernels contained about 60 percent oil, 30 percent total carbohydrate, 3 percent ash, 8 percent crude protein, 1 percent crude fiber, plus 10 mg vitamin C per 100 g.[8] Reportedly, it is also rich in beta-carotenes.[9]

Although such high oil content gives remarkable food-energy values, other reports have quoted oil contents up to and beyond 70 percent.[10]

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[7] Akubor, 1996, op. cit.

[8] The figures are calculated on a dry weight basis. The kernels measured were those of *Irvingia wombolu*. Ejiofor, M.A.N., S.N. Onwubuke, and J.C. Okafor. 1987. Developing improved methods of processing and utilization of kernels of *Irvingia gabonensis* (var. *gabonensis* and var. *excelsa*). *Int Tree Crops J.* 4(4):283-290.

[9] Obioma U. Njoku, L. and J. Obeta Ugwuanyi. 1998. Nutritional and toxicological properties of Dika fat (*Irvingia gabonensis*). *J. of Herbs, Spices & Medicinal Plants* 4(4):53-58

[10] Leakey, R.R.B. 1999. Potential for novel food products from agroforestry trees: a

According to one report the oil was made up of 39 percent myristic acid and 51 percent lauric acid.[11] Such saturated fats may not be the Western World's ideal in edible oil but they still merit recognition in hungry nations with high levels of marasmus, the form of malnutrition deriving from too few calories.

The amino acids in these seed kernels are reasonably balanced for human nutrition. In one test, lysine, tryptophan, valine, threonine, isoleucine, and phenylalanine were the essential amino acids whose levels compared favorably with the FAO/WHO provisional pattern for proper nutrition. Methionine and cysteine were deficient, and were the first limiting amino acids.[12]

In addition to food energy and quality protein, the seed could be a potential source of potassium, calcium, and phosphorus. The levels of iron, zinc, copper, and manganese are said to be low, but their levels probably depend on the local soil. The total oxalates are low when compared with other vegetables, so these antinutritional factors are unlikely to interfere.

The kernel's food-thickening property is thought to be due to mucilaginous polysaccharides that become more viscous with cooking. This unusual characteristic has been called "drawability."

HORTICULTURE

Horticulturally speaking, dika suffers from the fact that it has never been a managed crop. Nevertheless, it seems likely to respond to conventional horticultural practices. As far as field cultivation is concerned, it is known that the growth from seeds is slow. In addition, unless the seeds are handled carefully, most fail to germinate. According to one recent report, drying the seeds slowly under ambient conditions and subsequently soaking them for a day gives 100 percent germination.[13] And it has been found that certain seeds certainly don't require 10 or 15 years to fruit. In trials many trees flowered in about a third that time—not so different from apple and most orchard crops.[14]

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review. *Food Chemistry* 66:1-14.

[11] The seed was from Cameroon. Unpublished data from Hellyer in Leakey, ibid.

[12] Eyo, E. S. and H. Abel. 1979. Untersuchungen zur Fettsaurenzusammensetzung der Samen von *Irvingia gabonensis*, *Cucumeropsis manni* und *Mucuna sloanei* aus Nigeria ("Investigations on the fatty acid patterns of the seeds of *Irvinga gabonensis*, *Cucumeropsis manni*, and *Mucuna sloanei* from Nigeria."). *Der Tropenlandwirte* 80:7-13.

[13] Omokaro DN; Nkang A; Nya PJ. 1999. *Seed Science and Technology*, 27: 3, 877-884. The seeds were dried for 72-84 hours and then rehydrated for 24 hours. Within 33 days all of them had germinated.

[14] Ladipo and Anegbeh, 1995, reported in Ladipo, D.O., J.M. Fondoun, and N. Ganga. 1996. Domestication of the bush mango (*Irvingia* spp.): some exploitable intraspecific variations in west and central Africa. In *Domestication and commercialization of non-timber forest products in agroforestry systems*. Non-Wood Forest Products 9. FAO, Rome (available on-line via fao.org/documents).

It is known, also, that grafting, budding, air-layering, marcotting, and cuttings are all feasible, at least when applied on young wood. In addition, it has been discovered that many dika trees on Cameroonian farms had arisen from transplanted wildlings.

HARVESTING AND HANDLING

As far as best practices for handling, not much is reported. One study showed that fruits harvested at the mature green stage and ripened at 26-29°C were preferred to the naturally tree-ripened fruits in color and texture, although their overall composition remained unchanged.[15]

LIMITATIONS

The complexities of such things as flowering and fruiting are little understood. Anyone endeavoring to manage a dika plantation will be a true pioneer. In any such effort it is crucial to start with plants possessing the genetic capacity to produce well. In this regard, researchers at Onne in southeast Nigeria, have found that different trees demonstrate vast variation. For example, in 1995 one young tree produced only 18 fruits while its neighbor yielded 207.[16]

To extract the kernels the shells are currently broken open by hand. Different countries favor different techniques. Some extract the seeds from the fresh fruits as practiced by fruit collectors at Enugu. Others ferment the fruits and extract the kernels wet, while yet others ferment and sun-dry the seeds before cracking open the hard, dry shells. All these methods are problematic. The whole operation is exceptionally tedious and absorbs untold proportions of the villagers' lives.

NEXT STEPS

What could the world do to advance dika? Almost everything. Examples follow.

Extension Support With no extension support for dika farmers, anyone possessing a tree is on her own. One simple thing that could help such worthy souls is capacity-building specifically for their needs. This might involve practical training to pass on the techniques and requirements for successful cultivation. It might also involve demonstration plots where farmers can see and learn how the tree is best treated. And it might even include incentives to small farmers.

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[15] Fruits held at 12-15°C developed symptoms of chilling injury. Joseph, J.K., and O.C. Aworh. 1991. Composition, sensory quality and respiration during ripening and storage of edible wild mango (*Irvingia gabonensis*). *Int. J. Food Sci. Tech.* 26:337-342.
[16] Ladipo, 1996, op. cit.

In a related effort, green-fingered individuals should set up elite germplasm plots and sell or supply grafted plants to villagers. The current "superior" germplasm currently being evaluated may help to improve farmers' welfare if it is a big improvement over the average dika material today's farmers rely upon.

In general, then, emphasis should be placed on the mass production of planting materials using vegetative propagation and skilled professionals.

Document Cultural Traditions It is reported that the Baka of the Dja Forest (Cameroon) and the Ibos of southeast Nigeria have a wealth of insight into their local dika trees. Other peoples certainly have knowledge to share as well. The opportunity to tap the experience of farmers who have lived their lives with dika should not be missed.

Horticultural Development As already noted, vegetative propagation is the key to the process. Currently, studies are in progress in Nigeria and Cameroon to improve dika air layering, grafting and budding, all of which are means of propagating from the mature crowns of selected trees. The use of cuttings would be an especially attractive alternative as it avoids graft incompatibilities and potentially can produce large numbers of trees. Simple, low technology methods have been developed for juvenile shoots,[17] but getting successful cuttings from mature shoots is still an unsolved challenge.

Desirable improvement objectives include increasing fruit size, improving the taste of fruits, increasing yield, and reducing tree height and the time to bear fruits. It is already clear that dika trees vary hugely in fruit and kernel traits. It is also already clear that the potential for selecting trees with superior characteristics is great. These elite specimens are candidates for vegetative propagation. Finding them across thousands of kilometers of difficult terrain is the problem, but it is a far-from-insoluble one.

Already a few germplasm collections have been made. In Nigeria, for instance, genebanks have been established at Ibadan (in collaboration with the National Centre for Genetic Resources and Biotechnology) and Onne (in collaboration with the International Institute of Tropical Agriculture, IITA). In Cameroon a dika genebank has been established at M'Balmayo (in collaboration with the Institut de Recherche Agronomique pour le Développement). More should be set up in Congo, Gabon, Côte d'Ivoire, and so forth.

The existing collections, together with observations on field-grown trees, have already revealed individual specimens that could promote rapid progress towards domestication. These unusually promising variants include:

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[17] Shiembo P.N., A.C. Newton, and R.R.B. Leakey. 1996. Vegetative propagation of *Irvingia gabonensis*, a West African fruit tree. *Forest Ecology and Management* 87:185–192.

Collecting dika germplasm in Southeast Nigeria. The tree thrives in tropical Africa, and its special adaptation to heat and humidity raises the possibility of improved forms being employed as an eco-friendly crop for dense, moist, heavily shaded conditions. Also, dika holds promise as a crop for controlling soil erosion. Thus, it could be used to benefit the ecosystem whose future so many worry about today: the African rainforest. Here, two (female) students and two farmer volunteers show off the results of a day's search. (Paul Anegbeh)

- *Multiple Bearing* In several countries dikas that flower and fruit several times in a year have been observed. Among the 182 trees planted in 1990 at the IITA Station in Onne, Nigeria, for example, a few flower two, three, or even four times annually.
- *Precocity* Some seeds produce plants that start fruiting at a far younger age than expected. Of the trees mentioned above, about half flowered within five years. Some even set fruit twice a year by then.[18]
- *Good Form* Branching and tree form can be key to a successful orchard in fruit and nut trees. Dwarfing is an especially valued trait because it greatly simplifies the harvest. So far, dwarfs have not been found or created (by grafting, for instance), but have been developed by marcoting.
- *Split Fruits* During 1995 dika collections in the north of Gabon, a tree was found whose nuts split open naturally. When its fruits were spread out to dry, 93 percent had split open after 72 hours; none of the seeds from six other Gabonese dika trees had split at all.[19]

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[18] The seeds were planted in 1990. By 1994, 83 of the trees (45 percent) were flowering; by 1995, 100 (55 percent) were flowering.
[19] D. Boland, ICRAF. This remarkable tree was discovered on a farm near the town of Bibas. The scientists named it G28. Seed samples have been planted in the dika

- *Color* On a typical dika, the young leaves are pale green although some can be pink. But on a few trees the leaves remain red even when mature. This phenomenon apparently occurs only in the fruit-type species (*Irvingia gabonensis*). This quality could presumably be captured by vegetative propagation. Rosy-leaved dika trees might have potential for amenity plantings throughout western Africa, if not the whole tropics.

Plantation Trials The germplasm and knowledge already assembled indicates that dika domestication can enhance the human nutrition, natural environment, and local economy of the places where the species occurs. For the present we hesitate to recommend full-scale commercial plantings, but now is certainly the time to continue establishing ever-more sizable trials on research stations and on farms to test performance of the best genetic stock currently available. Also, it is not too soon to start large-scale demonstration trials in the right rural areas.

Expanding Markets Governments, good-will organizations, and activated individuals need to pool their efforts to increase and regularize the wider use of dika products. This should help rural people, rural economies, and rural environments. Even now many Africans depend on dika and other non-timber forest products for their livelihood. In a survey made in Cameroon's humid forest zone, sales of the four main non-wood native forest products[20] amounted to at least US$1.75 million in the first half of 1995. More than 1,100 traders, mainly women, were engaged in distributing the wild-tree products. Furthermore, the traders reaped a 30 percent mark up on each sale. But in the future even more Africans could benefit. The potential for expanding production and trade are good. Contrary to international belief, this sustainable use of living trees is not a dying business. Increased urbanisation is actually encouraging market expansion, as transplanted countryfolk living in the cities pine for the tastes of home.

Dika nut may also find a market beyond Africa. Indeed, it is a good candidate for "green marketing" in places such as Europe and North America. Exporting dika products such as thickening agents, oil, ogbono soup cubes, and the rest will provide incentive for West and Central African farmers to diversify and control quality. This will generate income for subsistence farmers, and create export revenues for countries in desperate need of them.

Quality Control Most non-wood forest products are still collected and marketed informally, with little organized oversight. The result is an

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genebanks at Onne (Nigeria) and M'Balmayo (Cameroon).

[20] In order of importance, the four were butterfruit (*Dacryodes edulis*), dika, abata cola (*Cola acuminata*), and erimado (*Ricinodendron heudelotii*). Butterfruit is featured in the companion volume on Africa's fruits.

unreliable resource. Now is the time to introduce various safeguards, performance standards, and a pricing system reflective of quality. Farmers will then strive to reap the reward of greater profit. The result will be superior products, a reliable resource, and better off farmers.

In southern Nigeria, where ogbono is consumed extensively, various growers, wholesalers, and consumers have already begun the process of upgrading the supply. They've proposed quality classes for dika kernels, ranging from Grade A (the top) to Grade D. To encourage the further use of dika-kernel oil, a quality standard for pharmaceutical grade oil has also been proposed.

Protection Although the species is still relatively common and widespread, many wild stands are in decline owing notably to pressures from logging and human settlement, as well as to the plant's reluctance to regenerate. Various animals, including elephants and lowland gorillas, love the mango-like fruits and disperse the seeds. But without those creatures the species apparently has difficulty regenerating. In certain regions of Côte d'Ivoire, for instance, people replanting dika seed around their village are the only ones sustaining this age-old resource.

What anyone could do about this is not so clear, but a few possibilities come to mind. For one, across the species' range the destruction of these exceptionally useful trees, which provide food and income for up to a century, should be minimized. For another, the few locations where dika diversity is especially high should be conserved. And the replanting of dika trees should be everywhere encouraged.

Food Technology Food technology could do wonders for the dika business, and it provides a powerful way to open new markets. Among the most crucial needs is a nut-cracking device.

One special use for processed dika may be as a generalized food thickener. Indeed, a polysaccharide chemist could well have a field day exploring the ingredients and properties of this barely studied material. Dika nut meal reportedly absorbs water and fat better than raw soymeal does, and "hence may have useful applications in processed foods, such as bakery products and minced meat formations."[21]

The kernel's food-thickening property is, as previously noted, thought to be due to mucilagenous polysaccharides that increase viscosity with heat. This characteristic "drawability" is an important trait for genetic selection, and through its development food technologists could provide exceptional input into the dika-domestication activities. Without that input, the plant-domestication efforts may create magnificent trees whose seeds are spurned

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[21] Giami, S.Y., V.I. Okonkwo, and M.O. Akusu. 1994. Chemical composition and functional properties of raw, heat-treated and partially proteolysed wild mango (*Irvingia gabonensis*) seed flour. *Food Chem.* 49(3):237-243.

by consumers because they just don't make an ogbono soup that is slippery enough on the palate.

Nutrition For a food as widely used as this one, there is an perplexing lack of nutritional information. Not only are rheological analyses needed, but chemical, biochemical, and nutritional trials should be run in both laboratories and clinics.

SPECIES INFORMATION

Botanical Name *Irvingia gabonensis* (Engl.) Engl. and *Irvingia wombolu* Vermoesen.

Synonyms There are many, such as *Mangifera gabonensis* Aubry-Lecomte ex O'Rorke, but in practice both species are field-recognized as *Irvingia gabonensis*. Formerly, the sweeter form was considered to be *Irvingia gabonensis* var *gabonensis*; the bitter form (now *Irvingia wombolu*) was *Irvingia gabonensis* var *excelsa*.[22]

Family Irvingiaceae (also placed in Simaroubaceae)

Common Names

English: bush mango, wild mango, dika, dika nut
French: manguier sauvage, chocolatier
Hausa: Agbalo
Nigeria: oro, oba, abesebuo, goron biri, oro, moupiki, muiba, eniok, andok,
Ibo: ogbono (kernels)
Afemai (Edo): ikpe (*I. wombolu*); ogi (fruit of *I. gabonensis*)
Yoruba: apon
Sierra Leone: bobo
Côte d'Ivoire: boboru, wanini
Cameroon: andok
Batanga (language in prime dika country near Kribi, Cameroon): mbumbwe'bo, nja'a
Congo: meba, mueba

Description

The dika is a deciduous tree reaching heights of 30 to 40 m. The bole, usually straight and cylindrical, is covered by a scaly gray bark that flakes away in plates. The trunk is typically short and slightly buttressed, with a

[22] The binomial comes with various "authorities," such as *Irvingia gabonensis* (O'Rorke) Baillon and *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baillon.

diameter of 1 m and more. The smooth leathery leaves are attached to the stem alternately. The flowers are greenish yellow, as are the open-pollinated, mango-like fruits.

The heartwood is pale-green, brown, or orange yellow, fading on exposure to a gray brown. Sometimes, it develops dark gray streaks. The sapwood is lighter, but is not always differentiated. In woodworking terms, the texture is fine to medium, the grain straight to interlocked, and the surface is without luster.

Distribution

Within Africa Dika is found in the western and central tropics, from southern Senegal to the northern tip of Angola (notably Cabinda), including Congo, DR Congo, Nigeria, Príncipe, Ghana, Côte d'Ivoire, Guinea, Sierra Leone, Sudan, and western Uganda. It is often found near riverbanks and reaches optimal growth in the dense evergreen rainforest.

Beyond Africa The tree is apparently unknown outside the African continent.

Horticultural Varieties

No named varieties are yet in commercial use.

Environmental Requirements

The outer limits of its cultivation are unknown, and whether the present occurrence is truly representative is uncertain.

Rainfall Although the tree probably cannot survive drought, it is generally unaffected by heavy rainfall (so long as the soil does not become waterlogged). It performs well at Onne, Nigeria with an average of 2400 mm of rainfall annually.

Altitude This is exclusively a lowland species, but whether that is a genetic imperative is uncertain.

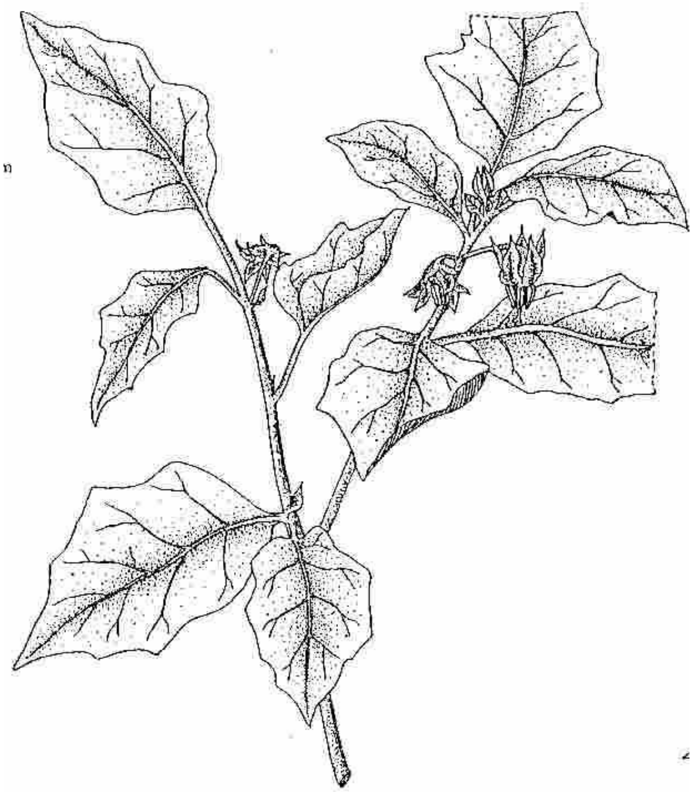
Low Temperature Dika trees probably cannot take freezing weather and even temperatures that approach freezing may damage them, although in the absense of any trial of cold conditions that is speculation.

High Temperature Given the tree's native habitat, it seems safe to say that it can withstand warmth.

Soil As earlier reported, dika occurs in fairly wet, well-drained, loamy-to-clay soils. The assumption for now is that it is restricted to such sites.

Related Species

In Southeast Asia a few dika cousins can be found. Mainly, they are renowned as prime candidates for high-priced tropical timbers. But one, *Irvingia malayana* Oliver ex Bennett, is the source of a vegetable oil called "cay-cay fat." In Nigeria are found two other species, *Irvingia smittii* Hook.f. and *Irvingia grandifolia* (Engl.) Engl, the latter used as timber.



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EGGPLANT (GARDEN EGG)

Late in the 1500s British traders introduced London's greengrocers to a strange new vegetable they'd picked up along the coast of West Africa. By 1587 this so-called "Guinea squash" was on English dinner tables. Although eaten as a vegetable, it was actually a small fruit about the size of a hen's egg. It was the same color as a hen's egg also. This pure white ellipsoid made an eye-catching eatable, which for obvious reasons the public soon dubbed "egg-plant."

At roughly the same time another vegetable also appeared in Britain. This one had fruits nothing like eggs. They were much larger, deep purple in color, and irregularly misshapen. For all their differences, though, the two plants were botanically related and shared common culinary characteristics.

For a while both were used. Eventually, however, the Guinea squash lost its toehold, and fell out of Western cuisine. The newcomer, on the other hand, not only survived but also took over its predecessor's felicitous name. This is how a purplish blob, looking like no egg seen since perhaps the dinosaurs, came to be misnamed "eggplant." The interloper[1] that stole an African plant's good name hailed from Asia, where it has been cultivated more than 4,000 years. In the Far East it even now holds a position comparable to that of tomato in other parts of the world. Indeed, it is sometimes referred to as "Asia's tomato."[2]

In recent centuries this versatile purplish vegetable has gone global in a big way and is now part of virtually every cuisine. It is fried, grilled, roasted, boiled, seared, baked, steamed, mashed, pickled, stir-fried, pureed, and otherwise prepared by many peoples. To give just a smattering of examples: Greeks, Italians, Syrians, and Egyptians all feature eggplant as daily fare. However, in the love of this bland and humble food none surpass the Turks, who claim to know a thousand ways of preparing it.[3]

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[1] *Solanum melongena*. Also known as brinjal or aubergine.
[2] China and Southeast Asia together contribute 78 percent of world production, and in Japan eggplant is the fourth-most-important vegetable, after sweet potato, radish and Chinese cabbage.
[3] Turkey actually grows about 20 percent of the world's production—more than the rest of Europe combined.

This worldwide popularity is something of a mystery. Lacking in nutritional quality, high monetary return, or even flavor, the eggplant has in some strange way insinuated itself into myriad local specialties. Indeed, it is the heart of famed national dishes, including: moussaka,[4] baba ghanoush,[5] ratatouille,[6] and Imam bayaldi.[7] And Sicilians, who certainly know a thing or two about fine dining, rave over caponata.[8]

Because of the general trend toward ever-greater reliance on vegetables and on diversity in diets, the enigmatic eggplant is growing in global popularity faster than ever. Already, it has taken firm hold as a meat substitute. Popular vegetarian dishes now include such things as eggplant Parmesan, eggplant lasagna, eggplant curry, and even eggplant chili. The vegetable also lends splashes of purple to trendy modern sautés, ragouts, pizzas, or vegetable Napoleons.[9] It has even become big in the self-styled capital of cuisine: New Orleans.[10]

While this culinary juggernaut commandeered the world of cuisine, the original eggplant—the Guinea squash—was left to languish. Four centuries later it remains unknown to the West and to modern horticultural science. Yet it too possesses an array of gastronomically interesting qualities. It, too, could be a globetrotter, not to mention a much bigger contributor to Africa's own food supply.

Although used like its Asian cousin, Africa's eggplant is quite different in appearance. Most of its fruits are sized and shaped like eggs. Indeed, many are reminiscent of a pointy tomato, a species to which they are so closely related that they can be considered Africa's answer to South America's tomato.

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[4] Among the Greeks' many eggplant recipes, moussaka is the most famous. It's basically an older version of Italian lasagna, with eggplant slices subbing for layers of flat pasta. It typically includes ground lamb, onions, and pungent-sweet spicing.

[5] Eggplant, roasted in an oven or barbecue grill, is the basis of Greek and Middle Eastern dips and spreads. Baba gannoush (also spelled gannouj) is best known.

[6] A famous French dish from Provence, ratatouille is a kind of vegetable casserole, in which each vegetable is cooked separately to its own specifications then turned into a luscious melange.

[7] Imam bayaldi, a mashed-eggplant dish, is named after the legendary moment in the 16th century when a religious man waited to taste a sample being served by a beautiful woman. As she bent over to present the plate, the veil slipped from her face. Imam bayaldi means "the leader has fainted."

[8] Caponata is an eggplant relish with a tantalizing sweet and sour flavor. It may be spread on pasta or on bread and eaten as a sandwich. It is also served with meat, poultry, or fish.

[9] Napoleons are layered foods, best known as desserts or pastries. In this case, the cook starts with a round of eggplant and tops it with slices of such things as zucchini, onions, peppers, mushrooms and dried tomatoes and cheese. The resulting pile is then baked.

[10] "We do like eggplant here in New Orleans," writes a local journalist. "We chop it and saute it, batter it and fry it, mash it and season it, stuff it with meat, seafood, oregano, breadcrumbs and itself. Oh yes, some chefs these days even turn it into soup, often with coconut milk to remind us where the stuff actually comes from."

The brightly colored fruits known as garden eggs are a significant vegetable resource almost Africawide. The crop is high yielding, easy to grow, and simple to harvest and handle. It is integral to many cuisines, cultures, and economies. Yet in many parts of Africa there is considerable scope for producing much better varieties in much better quantities. (G.W.M. Barendse)

This is among the most appealing vegetables the eye can see. Few others boast such rich colors. Among Africa's overall eggplant diversity it is possible to find fruits in white, cream, yellow, green, lime, orange, pink, red, plum, burgundy, lavender, violet, purple, or dusky black. Many come striped and multi-colored. And all possess a glossy skin that tends to shimmer in the sunlight. Beyond being egg-shaped, they can be also round, flat, ribbed, and pumpkin-like. Some get to be as imposing as beefy tomatoes; in general, though, they closely emulate chicken or duck eggs in size. Most start out white, and are normally eaten before exposing any hint of the final color they will ripen into.

Because the taxonomy of the different African eggplants is too complex and uncertain to bother with here, we have chosen to highlight a single

species, *Solanum aethiopicum*. In fact, we highlight only one of the four groups recently identified within that species (although much of what is said applies to all African eggplants). In English, fruits of this so-called Gilo Group go by names such as scarlet eggplant, mock tomato, garden egg, garden huckleberry, or gilo. They are the most widespread eggplants cultivated in Africa, and can be found from southern Senegal to Nigeria, from Central Africa across to eastern Africa, and from Central Africa south to Angola, Zimbabwe, and Mozambique. And they are almost certainly the original "Guinea squash" Londoners were admiring 500 years ago.

Many gilo cultivars have fruits that are delicious raw—both when immature *and* fully ripe. They can be chewed, sliced, or pureed into juice and eaten fresh like tomatoes. Depending on type, some are sweet, others bitter (a feature many Africans prefer in a vegetable). At a glance, those in the know can distinguish the sweet cultivars, whose fruits possess smoother skin and a more evenly rounded profile.

Despite international obscurity, this is a resource of considerable economic importance. Throughout Africa local garden eggs are very popular and play an important part in many diets. They have a long storage life (up to three months) and transport well. They are also often dried for use later in the agricultural cycle when fresh foods are unavailable. They (as well as the leaves of some cultivars) provide a reliable and continuing source of income for millions of farmers, most of them women. In rural districts from Senegal to Mozambique, a common sight is women hefting baskets of garden eggs on their heads to sell in nearby villages or townships. The crop is mostly grown, harvested, and marketed close to home, and it forms a crucial part of both the rural economy and the female existence.

The plants are notable for yielding a lot from a little space. They can produce a profit from the tiniest plots; even a few plants grown in garden pots can provide a worthwhile harvest. The plants are easy to raise, relatively free of disease and pests, and provide a steady supply of both food and income.

Like their famous Asian cousin, these vegetables seem at first sight to be hardly worth attention. They are mild in flavor and not especially nutritious. And they certainly don't light up the meal on the dinner plate—once cooked they usually end up a brown and squishy mass.[11]

Clearly, though, this country cousin of a booming global resource should not be left languishing in the scientific wilderness. Because it remains largely unsupported by research, it nowadays falls far short of its potential. At present only a handful of researchers are championing its cause, but this small group is enthusiastic about the crop's promise. Given attention, they say, Africa's own eggplant could achieve a very big future. And they are

[11] This is also true of the best-known eggplant, which similarly discolors upon contact with the air. "Eggplant pulp will, upon cooking, turn a murky shade of brown and the consistency of mush," a food writer explained in the *Washington Post* newspaper.

right: In this neglected vegetable there is a whole new world of colors, textures, flavors, and culinary uses to explore and exploit. If the common eggplant provides any guide, the African counterpart offers a foundation for myriad flavors, textures, and ingredients in meals celebrating dozens of local traditions, cultures, and food combinations.

Why should Africa invest time and effort on these crops? Beyond the reasons referred to above lie further justifications. The plants, for example, are very adaptable and can be grown in widely different climates. They are fast maturing and yet can be harvested over a period of time, so they yield both quick results and extended ones. They could notably benefit soil conservation activities, especially when used to quickly cover bare soil in the spaces between the farm's main crops. They tend to tolerate shade and so can be fitted in around various taller plants, such as bananas, cassava, and trees.[12] They are suited to infertile sites and benefit various difficult soils, and are likely candidates for wringing income from numerous kinds of "agricultural wastelands."

Because of their partiality for small spaces, this is a crop for city gardens squeezed in among the structures of modern life: high-rise buildings, factories, shanties, roads, train tracks, and chain-link fences. This is already apparent in African cities. A survey in Dar es Salaam, for example, found that the most frequently grown non-leafy vegetables were (in order of importance): tomato, common eggplant, African eggplant, sweet pepper, hot pepper, okra, cucumber, and carrot.[13]

To sum up: The local garden eggs are significant vegetable resources almost Africawide. They are good for nutrition, rural income, and soils. They are high yielding, easy to grow, and simple to harvest and handle. They are vital to local cuisines, local economies, and local cultures. They have untapped potential waiting to be brought out by research. In many parts of Africa there is considerable scope for producing much better varieties in much better quantity. They also have notable market potential and could become the cornerstone of localized rural economic development. And there is even potential for exporting African eggfruits to Europe and North America and earning some hard currency.[14]

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[12] One study (in Java, where these African eggplants are known) showed that 35-60 percent shade does not affect the edible yield of the species.

[13] The authors found that the leafy vegetables being most commonly cultivated in Dar es Salaam were: leaf amaranths, sweet potato leaves, pumpkin leaves, cassava leaves, cowpea leaves, Swiss chard, chinese cabbage, African kale (*Brassica oleracea* var. *acephala*), and nightshade (*Solanum scabrum*). Leaf amaranth is dealt with in Chapter 1; okra in Chapter 16.

[14] Caribbean nations already export African eggfruits to Europe under their local name "anthora."

Yeji market, Ghana. Throughout Africa local garden eggs provide a continuing source of income for farmers. In rural districts from Senegal to Mozambique women are commonly seen hefting baskets of them on their heads to sell in nearby villages or townships. Yet these vegetables have untapped commercial promise and could become the cornerstone of localized rural economic development. (FAO photo/P. Cenini)

PROSPECTS

The years ahead will likely see this become a rising star of the vegetable kingdom.

Within Africa

Humid Areas Excellent. The African eggplant species are generally resistant to the molds, mildews, and other fungal scourges that achieve their greatest development in the lowland tropics' heat and humidity. According to reports, they even show resistance against some of the worst soil-borne plant pathogens—including *Fusarium oxysporum* and *Verticillium dahliae*—and may have potential as tools to avoid soil sickness (see later).

Dry Areas Good. These plants are moderately drought resistant, and with them irrigation is rarely needed. The exact level of drought tolerance is untested, but African eggplant is known to survive dryness better than the Asian counterpart.

Upland Areas Probably excellent. These perennial plants are virtually always grown as annuals, and with their fast maturity should fit well into many climatic niches with abbreviated growing seasons.

Beyond Africa

Garden eggs are already commercially grown in a few other places—notably Brazil, the Caribbean, and Southeast Asia. The Internet carries guidance on growing them in Britain.[15] We see no reason why this species cannot expand in global scope, although uncertainty fogs the exact extent of its adaptability to cooler climes.

USES

There are two food products from these plants, fruits and leaves.

Fruits Typically in Africa, the garden egg is chopped, cooked and mixed into a variety of vegetable, meat, or fish stews and sauces. Although bitter taste is a major characteristic, many African eggplants are sweet or bland, especially in the immature stages in which they are eaten. The unripe fruits are usually cooked in a sauce after being chopped, parboiled, ground, or otherwise prepared. Peeling is unnecessary because the skin becomes tender enough to be consumed along with the rest. They are among the few vegetables that reach full flavor only after being cooked *beyond* the crisp stage.

Leaves Africans eat the leaves of at least certain types of the Gilo Group eggplants. Although these leaves are high in solanine, which is toxic,

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[15] According to one report, the berries of all species ripen throughout the British summer, with most plants bearing green unripe and colored ripe fruits simultaneously .

cooking apparently renders them harmless.

Ornamental Uses Not too many vegetables can take your breath away just with their looks. But African eggplants can. The fruits come in types that can be very ornamental, gleaming in more colors than the rainbow. The plants themselves are attractive small bushes that can be light or dark green, or purple, with tiny to very large leaves.[16]

NUTRITION

These fruits are far from nutritional powerhouses—they contain 92 percent water, after all. Nonetheless, they also contain small amounts of protein, vitamins, minerals, and starch. They are moderate sources of beta-carotene, B vitamins, and C. They also contain calcium, iron, potassium, and probably other minerals.

By the standards of the modern Western world, this veggie is a diet-doctor's dream: low in sodium, low in calories, high in dietary fiber, and a good source of potassium. It is used as a meat substitute not because it is high in protein, but because its spongy texture easily absorbs the other food's flavor while providing a mouthfeel vaguely suggestive of the presence of meat.

The seeds scattered through the fruit also contain vitamin C and carotene and other nutrients.

The leaves are excellent sources of vitamins A and B (particularly riboflavin), calcium, phosphorus, and iron. They contain about 5 percent of a protein containing significant amounts of methionine, one of the essential amino acids most difficult to find in plant-based foodstuffs.

HORTICULTURE

This crop is mostly grown on a small scale in compound gardens. It likes full sun, well-drained soil, or raised beds.

Propagation is by seed, which can be broadcast or drilled directly into well-prepared ground. Typically, however, the seeds are first sown in boxes or nursery beds. Germination takes about a week. After a month, when seedlings are 5-10 cm high, they are transplanted into the garden beds. The plants take at least a further month to establish themselves, after which they develop strongly.

For fruit production, plants of the Gilo Group are typically spaced 1 to 1.5 m apart. This spacing allows for the vigorous horizontal branching of these deciduous shrubs, which grow 1m tall unpruned.

Although less susceptible to disease than many vegetables, the crop is

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[16] In this regard, it is notable that when the common purple eggplant first arrived in the United States it was grown for its beauty. That was in 1806 when Thomas Jefferson planted it at his home in Monticello. And the African ones are the most beautiful of all.

attacked by a fungal leaf spot and by several insect pests, including leaf beetle, moth larvae, bud borer, and sucking bugs. (The plants are normally grown during the rainy season, solely to avoid the pests that build up during dry weather.)

The plants branch profusely, a feature making weeding difficult. In time, however, this propensity itself helps by shading out most competitors.

HARVESTING AND HANDLING

The perfect eggplant is picked while still immature—about 70-90 days after sowing. At that point the skin is glossy and firm, the flesh white, and the seeds tender and fully edible. It is best to use a knife or pruning shears to cut the fruits from the plants. Harvesting continues over a period of 8-10 weeks. Yields vary, but in one test, three plants (grown on a small plot 1m x 4m) produced 10 kg of fruits.

The production of leaves usually involves different horticultural techniques. In this case, the plants are severely cut back to a height of not less than 5 cm after which a massive growth of young shoots occurs. Regular harvesting of the young shoots and debudding encourages the production of side shoots that extend the harvesting period. A total of five to eight weekly harvests are usually possible.

The post-harvest handling of the fruits has not been thoroughly evaluated, but the only unusual challenge noted is a rapid browning of the skin after harvesting. Growers currently minimize this by picking fruits gently and in the cool of the day, avoiding exposure to the sun, and—where possible—putting in cool storage for a few hours, but many tricks undoubtedly remain to be learned.

LIMITATIONS

The very thought of growing African eggplant is likely to raise hackles in some quarters. Its flowers betray its relationship to a notorious weed that adversely affects some of the world's main crops—the small, bell-shaped, purple bloom is utterly nightshade. Indeed, the whole plant looks like the black nightshade, *Solanum nigrum*.[17] For this reason, it will be difficult to promote it as crop plant in, for example, the United States, Canada, New Zealand, Britain, or Israel. Of course, the common eggplant is not problematic in those countries, but people bringing in its cousin will find the guilt-by-association with a more distantly related weed hard to overcome.

The Solanaceae (or Nightshade Family) is renowned for protecting its leaves with lethal compounds. The toxins occur to greater or lesser degree, depending on the species and the parts of the plant. Some solanaceous

[17] Several decades ago, the juice from squashed black-nightshade berries was estimated to damage more than 10 percent of the bean crop in Nebraska alone.

This is a resource that is easy to raise, relatively free of disease and pests, and capable of providing a steady supply of both food and income. The plants are notable for a capacity to yield a lot of food from a small space. It is also, as can be seen here, rich in genetic diversity. (G.J.H. Grubben)

species have perfectly edible parts but, despite all the evidence of their safety, people typically fear the worst. When the common eggplant was first introduced to Europe, botanists prophesied that consuming it would cause insanity.[18] Potato, tomato, and peppers—all of which are nightshade

[18] When the common eggplant turned up in England, John Gerard advised readers of his 1597 Herball to avoid it and "rather...to content themselves with the meate and sauce of our owne country than with fruit and sauce eaten with such perill; for doubtless these apples have a mischievous quality; the use thereof is utterly forsaken." In France, eggplant was rumored to provoke fever and induce epilepsy. One tome described it as having "fruit as large as pears, but with bad qualities."

relatives—were in their time claimed to be deadly too.[19] African garden eggs can expect the same.

A third misunderstanding likely to limit support for African eggplant has to do with the crop's public image in Africa, where it is seen as a low-status vegetable associated with poor people. As evidenced by poor-person's crops before it—potato, soybean, peanut, pea, oats, and barley, among them—this mindset can hold back a truly exceptional new food for decades or forever.

The garden eggs (like the common eggplant) must be harvested at just the moment when the fruits have developed full size and still remain firm to touch. If they are left to mature, the skin turns dull, the flesh spongy, and the seeds turn hard and dark. Prompt picking also increases fruit set and boosts overall yields.

NEXT STEPS

For all intents and purposes, African eggplants have received no production research. Most national agricultural research or extension systems allocate no personnel or resources to these vegetables, which they generally consider low-priority species. This needs to change. Agriculture schools and farming programs across Africa should initiate localized eggplant support and improvement projects.

In addition, public interest in the greater use of garden eggs needs to be kindled. Indeed, these veggies could quickly fit into development-support programs across the continent—programs dealing with such things as urban agriculture, soil protection, traditional foods, home gardens, sustainable development, women's welfare, and rural development.

There is also a need to foster optimal cultivation practices. This is not a call for delay and long-term research operations; instead, it is a suggestion to take whatever knowledge is already available and make the most of it. In this regard, indigenous knowledge on the plant types used in the various countries should be gathered. Socioeconomic surveys on the production and use of garden eggs in traditional settings across Africa are warranted as well.

Programs to provide bulk samples of quality seed might also be helpful in promoting the greater appreciation for a neglected crop that is under almost everyone's nose.

Organizational Support At present, the exchange of eggplant germplasm and related information occurs mostly via accident and personal contacts. In practice, only a small part of the potential knowledge and germplasm is available to agronomists, vegetable breeders, growers, and whatever seed organizations exist.

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[19] According to accounts, the daredevil Colonel Robert Gibbon Johnson stood on the steps of the courthouse of Salem, New Jersey, and publicly defied death in 1820 by eating a tomato. A crowd was on hand to enjoy the spectacle of this fool's suicide.

As backup support, it would be good to have some sort of functioning African-eggplant promotion and coordination undertaking. This need not be elaborate or even formal—funding in this case being less important than any kind of forward movement. But a fiscal means for sustaining interest and providing specific help and stimulation would be exceptionally supportive.

One thing to be done is to gather the natural diversity of eggplant across Africa. As noted, the types to be found are amazingly varied. A start on this has been made already, and seeds of several different types are housed in the vaults of international seedbanks. But local initiatives can still do much to gather the germplasm in the exceptionally diverse and dispersed habitats, not so much to conserve it but to get the best into wider use.

Another thing is to establish an eggplant database, into which research information could be incorporated, and subsequently disseminated to farmers, researchers, and interested amateur gardeners. Accurate and illustrated botanical descriptions of the local 'cultivars' used as vegetables could also be useful.

Food Technology In the advancement of this neglected resource, there are many things to capture the interest of food technologists. For one, African eggplant should be tested as a substitute in recipes developed to exquisite perfection for its famous Asia-born counterpart in countries such as Greece and Turkey.

For another, although no specific mention of toxicity has been reported, this species belongs to a genus some of whose many members have poisonous leaves and sometimes also unhealthy fruits. This is now the time to clarify once-and-for-all the African eggplant's potential for disaster.

For a third, the whole issue of post-harvest handling of the fruits deserves to be analyzed and formalized.

Horticultural Development The species can be considered an almost-blank agronomic slate, and almost any studies relating to its production—from seeding depth to thinning the fruits to increase their size—merit clarification. Horticultural investigations are especially needed to determine the field conditions that promote optimal growth and maximal harvests.

Genetic Development There are excellent chances for genetically enhancing African garden eggs for increased yield and other features through simple selection and/or plant breeding (perhaps including hybridization). There is a need to create (or identify) varieties better adapted to specific growing conditions. In addition, there is potential to create varieties with fruits of even more shapes, colors, and tastes.

Fuller use of genetic diversity can also raise public and industry's use of the crop. That, in turn, will lift its commercial value and profile.

In biotechnology exist many other possibilities. Breeders can likely take

advantage of the advances made in related solanaceous species. For instance, genetic maps of potato, tomato, peppers, and the common eggplant are available. Markers common to African garden eggs and those well-mapped Solanaceae should be identified. Such markers should allow the molecular tagging of agronomic traits and provide powerful tools for breeding whole new worlds of African eggplants.

Genes for Improving Other Crops Because of their genetic closeness to major global crops in the Solanaceae, African eggplants may also provide powerful tools to the breeders of such things as tomato, potato, and eggplant. They contain several traits potentially useful in improving those crops. These include resistance to:

- atrazine (a herbicide);
- tobacco mosaic virus;
- potato late blight;
- phomopsis fruit rot; and
- verticillium wilt.

Genes for these might possibly be isolated from Africa's garden eggs and genetically engineered into eggplant, potato, tomato, and peppers.

In addition, the species has been reported as showing molluscicidal activity, and may prove useful in controlling garden snails, slugs, or maybe even the water snails that harbor lifestages of the schistosomiasis parasite.[20]

Moreover, it has been claimed that this crop serves as an alternative host for a variety of pests, bacteria, and fungi that affect a number of commercial crops. African eggplants might therefore be used to lure away the pests.

As noted earlier, there are indications that African eggplant is resistant to soil-borne diseases caused by the very serious pathogens, *Fusarium oxysporum* and *Verticillium dahliae*. Perhaps it has a potential to be used as a way to avoid soil sickness.[21] Scientific exploration is well warranted.

New Locations Should the outside world try African eggplants? We think yes. The crop already grows in Brazil, and its potential for other tropical countries is high. It may even prove successful in Mediterranean nations. Those are also the ones that rely on eggplant, and they may find the extra drought-tolerance of the African version notably valuable.

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[20] We are somewhat skeptical of this possibility because in England slugs are said to be among the crop's worst enemies.

[21] T. Yoshihara, Y. Hagihara, T. Nagaoka, S. Chiba and S. Sakamura. 1988. Fungitoxic compounds from the roots of the eggplant stock. *Ann. Phytopath. Soc. Japan*. 54: 453-459. The biologically active compounds have been identified as several kinds of sesquiterpenes.

Exports and Marketing Within Europe and the United States, there is a strong tendency toward horticultural diversification, not only in the size, shape, color and taste of the well-known fruits and vegetables, but also vegetables that are new to the markets. Furthermore, some new eggplant species could be introduced to satisfy the consumers' continual demand for novelty products.

Taxonomic Clarification *Solanum* taxonomy has been clarified and resolved so often that outsiders have almost lost faith. African eggplants offer a world of possibilities for overcoming taxonomic difficulties in this important family because they lie somewhere among potato, tomato, peppers, and the common eggplant. DNA and other sophisticated evidence might clarify and resolve the uncertainties all over again.

SPECIES INFORMATION

Botanical Name *Solanum aethiopicum* L.

Synonyms *Solanum gilo* Raddi, *Solanum olivare* Paill. & Bois. *Solanum pierreanum* Pailleux & Bois.[22]

Family Solanaceae (Nightshade Family) section Oliganthes

Common Names

Arabic: begingan et gut a
English: mock tomato, scarlet eggplant, Ethiopian eggplant, African bitter pea-aubergine, wild pea-aubergine, wild African aubergine, tomato-fruited eggplant, Ethiopian nightshade,
French: tamate amere, aubergine amère, petite bringelle maronne (Africa)
Nigeria: asun (Shum group), ikan, igba (Gila group)
Sudan: guta, quta, begingan et gut a (Ar)
Swahili: ngilo
Uganda: nakati, nakasuga (Lug), abugarra (Yr/Tr), (n)jagi (Ach/Gis), enjagi, entura (Yr/Tr/Kig), etanga (Ank)
Chinese: Xiao gu qie, Xiao ku fan qie (Cantonese)

Description

In the vegetative stage, a plant of the Gilo Group looks like a common eggplant (i.e., *Solanum melongena*). It is a fairly woody deciduous annual, or occasionally perennial, herb up to 100-150 cm tall. It is not prickly. The

[22] Other possible synonyms are *Solanum integrifolium* Poiret, *Solanum integrifolium* Poiret var. *microcarpum*, *Solanum naumannii* Engl., *Solanum zuccagnianum* Dunal

mature leaves are smooth, apart from minute glandular hairs. Features distinguishing it from the other species are the small, white, star-shaped flowers. In addition, the calyces are never long and the inflorescence has a short (1 cm) rachis. The fruits are 3-6 cm in diameter, varying in shape from ellipsoid to almost round. They contain 2-6 locules and are normally firmly attached to thick fruit stalks that turn downwards. The flowers are pollinated by large bees.[23]

Distribution

Within Africa The plant occurs in virtually all of sub-Saharan Africa, but is less well known in (maybe absent from) South Africa and Madagascar.

Beyond Africa Centuries ago, the plant was taken to Brazil, probably with the slave trade. Brazilians call it "gilo," a slight corruption of the name used in East Africa, ngilo.

Horticultural Varieties

There are few named varieties, perhaps better called local landraces.

Environmental Requirements

The crop's ecological requirements are thought to be much like those of common eggplant, although *Solanum aethiopicum* is probably slightly hardier, and more tolerant of drought.

Rainfall 500-1200 mm or more. The plants thrive during the rainy seasons in the tropics.

Altitude Up to 1200 m.

Low Temperature Optimal temperatures for the growth of these plants lie between 20 and 30°C, and perhaps higher, but the species likely will grow well at temperatures down to 15° C. (The optimum germination temperature lies between 15 and 30°C, although temperatures fluctuating between these values are apparently required to break the seed dormancy.)

High Temperature The species seem to grow well within an upper temperature of 35° C.

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[23] Contributor Barbara Gemmill wrote, "Eggplant flowers have "poricidal" anthers, which means a bee must bite the anther and vibrate its wings at a certain frequency for the pollen to be released (a process called "buzz pollination"). Only certain, usually large-bodied bees like carpenter bees are able to do this; honeybees cannot buzz-pollinate."

Soil An easily grown plant, it succeeds in most soils. Nonetheless, it does best in soils of high fertility, especially those high in nitrogen and phosphorus. Sandy loam to friable clay soils with a pH range of 5.5 to 6.8 have been declared "particularly suitable." However, one report from Britain notes that "providing the soil is well drained, the actual soil type appeared almost irrelevant to good growth."

Photoperiod Believed to be day neutral.

Related Species

Gboma eggplant The present chapter has focused on the gilo eggplant, *Solanum aethiopicum*, but it might well have dealt with this gboma eggplant, *Solanum macrocarpon*. The two are similar in all but a few details of the flowers and leaf hairs. Virtually everything said in this chapter is true also for the gboma eggplant.

This is another species that might be more widely and more intensively cultivated than at present. It is perennial, glabrous, and shrubby. Originally from tropical and equatorial Africa, but widely introduced into Southeast Asia, this species produces a small fruit similar to the eggplant. The fruits may be eaten when very small, often raw, but in many places the plant is grown chiefly for its edible leaves.

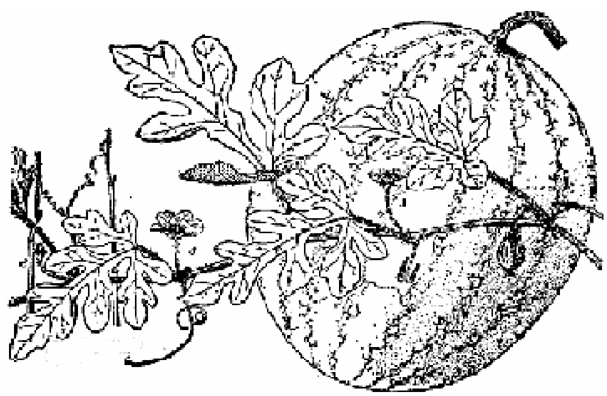
Truly lost "eggplants" In West Africa can be found *Solanum scabrum* L. and *S. americanum* Mill. The leaves of these two wayside plants, along with many other *Solanum* species, such as *S. nigrum* from the Americas, form the ubiquitous "African spinach", important (but potentially toxic) food resources that only recently have drawn the attention of scientists.

Close cousins There are, as noted, relatively distinct groups within the species *Solanum aethiopicum*.[24] Those with special potential are:

- *The Shum Group*. This has fairly small, subspherical fruits and small glabrous leaves. Only the leaf is used (the fruits being too bitter). It is distributed throughout Central Africa, as well as in western equatorial Africa, Nigeria, Benin, Togo, and Ghana.

[24] The species exists in different forms, which were in the past described as about 20 species. Recent studies have shown that all these plants are highly interfertile, and better treated as one species, having arisen by domestication from a single wild progenitor: *Solanum anguivi*. Four main groups of cultivars of *Solanum aethiopicum*, with different uses, are now recognized: the Shum, Kumba, Gilo and Aculeatum groups. The first three are native to Africa; the fourth grows in Europe, and has inedible fruits.

- *The Kumba Group*. This has much-lobed glabrous fruits that are pumpkin-shaped and only slightly bitter. When ripe, they are light green to red-orange—very ornamental and unusual looking with lots of bumps. Both leaves and fruits are eaten. The species is restricted to the sub-Sahelian region from Senegal to the top of Nigeria—a coverage reflecting that of the old Mali Empire.



8

EGUSI

The egusi plant looks so much like a watermelon plant that most botanists think it is one. The fruit looks so much like a small, round, watermelon that the two are also easily confused.[1] However on the inside the egusi fruit is neither red, nor luscious, nor sweet. Indeed, it is white and dry and bitter enough to be repulsive. This is one fruit not even monkeys bother with. But for all that egusi *is* a food crop…and far from a small one at that.

Egusi[2] is grown for its seeds, which resemble large, white, melon seeds. In West Africa, a region where soups are integral to life, they are a major soup ingredient and a common component of daily meals. Coarsely ground up, they thicken stews and contribute to widely enjoyed steamed dumplings. Some are soaked, fermented, boiled, and wrapped in leaves to form a favorite food seasoning.[3] They are also roasted and ground into a spread like peanut butter. Some are roasted together with peanuts and pepper and ground into an oily paste[4] that is used when eating kola nuts, eggplant, and fruits. Egusi-seed meal is compacted into patties that serve as a meat substitute. It is even said that the dry seeds placed on a hot skillet pop like popcorn and come out looking like puffed rice.

Beyond their use in processed form, egusi seeds are commonly parched and eaten individually as a snack. In his recollections of life in Ghana, one commentator notes: “Whenever a group of men were standing around talking, their hands were usually busy dehulling [shelling] egusi seeds.” And another recalling life in Cameroon notes: “On many an evening or hot afternoon in farming villages, women sitting with their families will be deftly and rapidly shelling the seeds ready for sale or home cooking.”

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[1] Watermelon is also an African native. For details, see companion volume on the fruits of Africa.
[2] In Ghana and a few other countries it is called “neri.” Egusi (some think the term derives from Yoruba; some from Hausa) has become the generic name for the seed across West Africa’s many linguistic boundaries.
[3] In Nigeria this is known as “ogiri-isi” and in Benin “avrouda.” It typically comes with or without dried shrimp.
[4] Called “ose-oji” in Nigeria.

Northern Namibia. This plant is easy to grow. Indeed, it survives on barren sites, not to mention some of the driest and most climatically challenged locations. Further, it blankets the soil and helps protect the land. Most of all, though, this vigorous annual suppresses weeds. After a month, fields planted with egusi are typically weed free. (Arne Larsen)

As we have said, this is no minor food. Almost all the big markets in Benin, Cameroon, Ghana, Nigeria, Togo, and the other nearby nations sell the seed. Egusi is in high demand in tropical markets, especially in the peri-urban and urban markets. Exactly how much is sold is unknown, but as far back as the 1960s Nigeria was annually producing 73,000 tons. Today the figure is likely much greater, and about a dozen other nations also grow egusi. The area under this crop is not insignificant, either. In Nigeria during the 1970-71 planting season more than 360,000 hectares were reportedly planted to it. In the 30 years since, egusi production has spread further.

Although outsiders might assume this melon seed to be merely a localized specialty, it actually has universally acceptable flavor and food-processing qualities. Indeed, it is already being introduced to other nations.

It is, for instance, available either whole or in flour form wherever African food is sold…notably in Europe and the United States. It is also peddled over the Internet, and apparently very successfully; search engines turn up scores of online egusi dealers.

Oil makes up the seed's largest nutritional component, averaging more than 50 percent...a figure so high that among major foods only peanut can match it.[5] In composition the oil is almost ideal. One recent analysis recorded its fatty-acid makeup as 63 percent linoleic and 16 percent oleic. And this highly polyunsaturated lipid is widely used. In northern Ghana one survey found that although shea[6] was the major cooking oil, egusi oil ranked next in importance.

Despite being a significant foodstuff even by global standards, egusi is hardly known to nutritionists outside a few West African nations. That is more than a pity; the seed could be an exceptional tool for nutritional intervention wherever protein-calorie malnutrition occurs. Although more than half its weight is edible oil, another 30 percent is protein. And that protein has high nutritional quality. The seed also contains important amounts of vitamins, especially thiamin and niacin. Additional dietary bonuses come from its levels of minerals.

This is a nutritional combination of unmistakable portent considering that the crop thrives where milk is largely unavailable (mainly because the presence of tsetse fly means an absence of cows). A high-energy, high-protein concentrate like this might ideally complement Africa's prevalent diets based on starch-rich grains (sorghum and maize, for instance) and roots (notably cassava). It doesn't take much of any food that is half oil and almost a third protein to provide the calories and amino acids that stressed, sick, and fast-growing bodies need each day. Egusi could thus be a vital tool against marasmus, kwashiorkor, and other debilitations.

This plant is not difficult to grow. Indeed, it grows so easily it could be called a farmer's friend. Many West Africans raise it and it normally yields very well for them. It is largely free of pests and diseases. It survives on impoverished sites and in forest clearings, as well as in some of the most climatically challenged locales. And wherever if grows the plant blankets the soil and helps protect the land. Most of all, though, this vigorous annual suppresses weeds. After 4 weeks of growth, fields with egusi in them are typically weed free.

Often the plant is grown alone. Sometimes it is grown in unused places around the fields, such as banks and bunds. But mostly it is interspersed among other crops, a combination that is especially appreciated because egusi takes care of the weeds. Normally, fields of crops such as sorghum,

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[5] The figure is based on the dehulled seed, the kernel, which is the edible portion. By comparison, peanut has roughly 48 percent oil and 25 percent protein. Soybean weighs in at about 18 percent oil and 38 percent protein.

[6] See Chapter 17.

WHAT IS EGUSI?

In this chapter egusi is presented primarily as the seed of one species, *Citrullus lanatus*, a type of watermelon. That species is indeed very popular, thanks to its productivity and food quality. But in reality, the situation is confused because the name egusi is applied generally to any of several similar looking seeds. All these seeds come from cucurbit species (family Cucurbitaceae) and all have high oil and protein contents. In some West African countries the main egusi crop may be *Cucumeropsis mannii* (*Cucumeropsis edulis*). Seed of the gourds *Lagenaria sicceraria* and *Telfairia occidentalis* are also consumed as egusi. All are cultivated on a large scale in West and Central Africa as they are easy to grow and their seeds are popular foods, and most of what we say here applies to them as well. Sometimes outside Africa, "egusi" can also refer to the bitter apple or vine of Sodom, C*itrullus colocynthis* (Linnaeus) Schrader; in turn, this scientific binomial is not to be confused with *Colocynthis citrullus* Linnaeus, which is a botanical synonym for *Citrullus lanatus*, the egusi treated here.

cassava, coffee, cotton, maize, or banana require two, three, or more weedings during the growing season. An intercrop of egusi cuts that to one.[7]

In spite of nutritional value and benefits to farmers and the land, this nutritious age-old resource is languishing. But this plant has so much to offer that it deserves concentrated local, regional, and international attention. A tasty seed that is not only rich in oil but rich in protein could be of exceptional value in most parts of Africa, especially where chronic malnutrition strains health and drains initiative. Indeed, egusi is already to be found in many of the nations on which dietary deficiencies hang heaviest, but is not being fully harnessed for humanitarian good.

Additional justification for the notion of a major egusi initiative comes from North American research. For over a decade U.S. Department of Agriculture scientists have studied the seed's nutritional and functional properties. The research leader, John Cherry, is convinced the crop has a future. "Egusi-seed flour contains excellent quantities of the major nutrients, oil, and proteins," he reports. "The essential amino acids in the proteins of

[7] To the farmer, this is a boon. Consider the conclusion of an article by the International Institute of Tropical Agriculture in Nigeria: "Studies at IITA and elsewhere show that crops such as maize and cassava interplanted with egusi need to be weeded only once (within 2-3 weeks) after planting if the melon is grown at densities of 20,000 plants per hectare….Ground cover by egusi suppresses weeds until the melon is harvested, by which time the crops have developed a canopy cover of their own." At that point, the main crop shields the ground and suppresses the weeds without egusi's help.

the flour make it a good vegetable protein."

A separate USDA research group has concluded that egusi could find a place in the food industry. Its promise is for thickening, stabilizing, and fortifying processed products. The group's analyses were mostly done on defatted, low-hull flour—the form most appropriate for processed foods. It proved to have high water and oil holding capacities; it formed thick and stable emulsions.[8]

Despite its promise for the food industry, it is the small-scale, subsistence use that most concerns us here. In this regard, foods produced from locally grown egusi seed could improve diets in many an African country whose population currently suffers inadequate diet. Egusi seed compares with the best-known high-protein/high-fat food plants, and it is indigenous. Noteworthy is the fact that the seeds can be stored for long periods. This is one oilseed that can supply quality food year-round.

Given attention, the plant is likely not only to improve nutrition but also farmers' income. A women's group of central Benin (Bante) cultivating 10 hectares of egusi earned more than they would have from cotton, the region's main cash crop.

Indeed, when grown well, egusi boosts soil quality too. And its benefits are likely to be felt not only in West Africa but also in eastern and southern Africa, and perhaps elsewhere.

Women would be special beneficiaries. Although in some places women grow egusi, in the main they are they the ones who harvest and process the crop. Generally speaking, they receive relatively high cash income for their work. Indeed, the "egusi wage" is regarded as the standard for women's agricultural payment for all tasks, and the women defend it with determination because it sets the standard of their lives. Any improvement in egusi's profitability will directly help millions of women of all ages and all rural jobs.

PROSPECTS

Although it now gets no particular support from national or international agronomic research organizations, egusi could be made into a nutritious and tasty food for much of the continent, if not the world. At least within West Africa, getting people to consume more and farmers to grow more should be easy, so long as seeds for planting are available and the harvest continues attracting a fair price.

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[8] The authors wrote: "Protein isolates that differ in gel electrophoretic patterns and amino acid content can be prepared from the flour in one- or two-step water and sodium hydroxide extractions," wrote the researchers. "The water and oil holding capacities of the flour are 0.7 and 2.6 ml/g, respectively. Thick (mayonnaise-type) emulsions form in the alkaline pH range and a stable foam forms at pH 5.0."

Within Africa

Egusi is notable for tolerating an extreme range of conditions, from damp to dry.

Humid areas More than a dryland plant, egusi (or its close relatives[9]) grows in equable sites. It is an especially promising food for the regions of lower West Africa, where cows cannot thrive and milk is in consequence a rarity.

Dry Areas As noted, the plant resists drought and has long supported people dwelling in West Africa's dry regions. It is not so drought resistant as to thrive near the true desert, but it is well adapted to the semiarid zone (incorporating, for instance, the Guinea savanna, Sudan savanna, and the sub-Sahelian region) that lies halfway between the Sahara and the sea.

Upland Areas Wherever watermelons grow, egusi should grow too. Thus, many tropical highlands as well as warm temperate locations are candidates for at least trialing the crop.

Beyond Africa

Egusi seeds are potentially a source of quality protein for many countries. However, beyond Africa they may not catch on in a big way. For one thing, consumers may not immediately take to eating a melon seed. For another, it is hard to produce this sprawling plant on a scale to compete with other mass-produced oilseeds. Egusi is therefore most likely to stay a specialty crop for sale in African food markets. However, roasted pumpkin seeds have become a fairly widespread snack in the United States; egusi could perhaps become a counterpart. Not only is it tasty and nutritious, it likely would sell at a premium.

USES

Even ignoring that some egusi-seed "suppliers" are gourds and melons with their own individual uses, this is a multiple-purpose food.

Seeds The seeds are shelled (dehulled) and the kernel is ground into a flour. As already mentioned, that flour enriches and thickens soups as well as other foods. The whole seeds are dry-roasted and consumed as a snack. Pounded roasted seed produces a paste. Known as ose-oji in Nigeria, this peanut-butter-counterpart may be spread on bread, mixed with other foods, or dropped into soups and stews.

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[9] The seeds seen in certain marketplaces certainly look like egusi but may well come from related species (see below).

London grocery store. Egusi is increasingly exported to Europe. In Brussels it is sold under the Congolese name, mbika. In Paris, retailers use the (North African, Asian and Cameroonian) name of courge. In London and Madrid, the seeds are sold under the commercial name of egusi. (Honoré Tabuna)

Oil In West Africa egusi oil is sometimes extracted, but so far only on a small scale. It is used in cooking and seems suitable as salad oil. The seed has occasionally been exported to Europe for processing into vegetable oil.

De-fatted Meal The solid remaining after the oil has been squeezed out contains 60 percent protein. This remarkable defatted solid can be ground into flour with myriad dietary uses. It is mainly used as a meat substitute.

Leaves It is reputed that the young, tender leaves may be cooked and eaten as a potherb.

NUTRITION

Despite its widespread importance as food, little nutritional detail is readily available to an international readership. In general, however, the kernel contains about 50 percent oil, 30 percent protein, 10 percent carbohydrate, 4 percent ash, and 3 percent fiber.

The protein content compares favorably with that in the most renowned legume seeds.[10] The exceptional level of essential amino acids makes the

[10] Egusi seed's protein content (average total nitrogen 5.75 percent) is higher than in

protein composition special. Egusi is an excellent source of arginine, methionine, and tryptophan. The biological indices of its protein quality have been described as: "lower than soybean but comparable to or higher than most oilseeds." Nutritionally, the limiting amino acids are lysine and threonine.

Several micronutrients also contribute to human nutrition. Vitamins occurring in notable quantities include B1, B2, and niacin. In one analysis the highest mineral component was phosphorus, followed by potassium, magnesium, manganese, sulfur, calcium, iron, and zinc.

Soluble sugars and starch make up the bulk of the carbohydrates.

Only a few nutritional trials have been conducted. In general, however, significant growth improvement was reported when egusi flour supplemented traditional West African diets. The biological value, net protein utilization, and protein-efficiency-ratio proved comparable to or higher than those of standard oilseeds. The results suggest that egusi seeds have good potential for fortifying both traditional and modern food formulations.

HORTICULTURE

The crop is usually handled like watermelon or pumpkin, species to which it is not only related but similar in plant type and agronomic need.

Propagation is exclusively by seed. Although the exact planting method depends on site and situation, most is sown during the major rainy season, typically after the first few heavy showers. Generally, two or three seeds are placed in holes about 2 cm deep. Where conditions are conducive to good growth the holes are normally spaced about 1 m apart and two plants are allowed to grow per hole. A pre-planting application of complete fertilizer followed by dressings of nitrogenous fertilizer at intervals to maintain a regular growth rate has been recommended.

This is how egusi is produced in the Transition Zone located between the dry savannas and the humid coastal area. There, the crop is grown in dense, pure stands and it achieves its best productivity. There, too, the soil tends to be fairly high in organic matter and fertility. Also, the rainfall is high (1,400 mm) and well distributed throughout half the year (April to October).

In the more challenging zone immediately to the north (the Guinea and Sudan savannas, for instance), egusi is more often grown as a mixed crop, especially on ridges between sorghum. The soils here are poor in both organic matter and fertility; the rainfall low (800 mm) and brief. As a result, wider spacing (about 3 m between plants) is necessary. Understandably, then, production-per-hectare is much reduced.

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peanut and cowpea and slightly less than in soybean (6.65 percent). One advantage over soybean is that egusi seeds need no processing…there are no antinutritional ingredients to remove.

Whatever the overall conditions, most seeds germinate and within a week seedlings are emerging. Three weeks later, the vines nearly cover the ground and flowering starts. Often the fruits are ready to harvest 120-150 days (4-5 months) after sowing. However, in some locations they take 180-200 days to mature. The vines then wither and die.

As noted earlier, neither pests nor diseases much affect the growing plant. Variegated locusts have been reported to eat egusi seedlings (and everything else of course).

HARVESTING AND HANDLING

Once the fruits stop enlarging they can be harvested. The timing, however, is not critical…this is one crop in which there is no particular urgency to bring in the mature fruits. Within reason, they can remain in the field without serious loss.

In better-watered areas with reasonable soil the harvest averages five fruits per plant. In drier and more barren locations the yield averages two fruits per plant. Normally a fruit weighs between 0.8 and 1.5 kg, but those grown in the more challenging climates tend to be smaller.

The fruits keep well, and can be stored several months without decaying.

To remove the seeds West Africans employ several age-old methods:

- They break open the fruits with a hard stick and lay the pieces on the soil pulp-side down. After several days the pulp has decayed, freeing the seeds.
- They bury the fruits whole, and leave them to decompose a month or so underground.
- They crack the shells, heap the fruits up, and cover the pile to promote decomposition.

Following any of these procedures, the seeds are easily separated by hand or by a stream of water. They are then washed to remove any remaining pulp fragments and allowed to dry in the sun. The dried seeds are best stored in sealed containers. Certain beetles can ruin the whole harvest.[11] But given care the seeds can be stored almost indefinitely.

Before use as food the seeds must be shelled. At present, this is mostly done by hand.

LIMITATIONS

The plant often seems quite susceptible to root-knot nematodes as well as to waterlogged soil.

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[11] These notably include the red flour beetle (*Tribolium castaneum*) and the cigarette beetle (*Lasioderma serricone*).

This sprawling species is poorly adapted for mechanized operations. It seems unlikely, therefore, that it could compete on the world stage for the industrial-scale production of cooking oil or protein concentrate.

Despite having fed generations of Africans and despite its promise for feeding future generations, egusi has had very little development support. There is no standard method for measuring its yield. Its biology is virtually unknown. Its nutritive value is based on only a few samples that may or may not have been nutritionally representative. Even its scientific name and genetic relationship to several related plants is not without doubt.

NEXT STEPS

This crop has such high prospects it deserves intense and far-ranging research. And it seems quite amenable to rapid progress. An annual, it gives results quickly. It is relatively easy to manipulate and propagate for the purposes of crop improvement. Seed is available. And there are no major technical barriers to be overcome before advances can be achieved. Indeed, it should be able to ride piggyback on a wealth of research already available from its relatives—watermelon, melon, squash, and pumpkin—thereby saving much time and money.

Publicity This is not a resource that needs much introduction, at least in West Africa. Nonetheless, the knowledge about egusi and its many uses should be brought together and made available for the benefit of all. One project could be the production of a Farmer's Handbook on the best methods for planting and managing the crop. Another might be a compilation of the greatest recipes from the countries where egusi grows. Cooking contests and other challenges would be both interesting and beneficial to the public awareness of the crop's importance.

Rural Development Taken all round, egusi offers one of the best interventions for raising farm performance and nutritional performance in West Africa (and perhaps many other parts of the continent as well). Although it is not a legume, the crop should be at least tested in programs that use legumes. It provides high-protein and high-oil foods like soybean and peanut as well as ground covering capacity like mucuna or lablab.

Malnutrition Could egusi be used as baby food? An NGO in Ghana reports that blending 200 ml of water with 240 ml of dehulled seeds, and seasoning the result with a little honey and salt produces a mixture resembling mother's milk. This smooth, milky, liquid might prove useful as an infant-food supplement where neither mothers nor cattle can provide adequate milk, they say. Perhaps this could open the door to the long-sought homemade weaning food containing both the high energy and the quality protein needed to combat protein-calorie malnutrition in the very young.

That is not too hard to imagine. Every home in every village has a stone mill or small mortar and pestle. Using such simple equipment, the seeds are easily crushed into a peanut-butter consistency.[12]

Studies conducted by the Nutrition Centre at Bawku, in the Upper Region of Ghana, on the use of egusi as a source of protein and fat in the diet of children who show the effects of marasmus (lack of calories) and kwashiorkor (lack of protein) has proved to be satisfactory. In Benin, the defatted egusi flour, known as *fagous*, is used to make cake and it is also added to baby food.

Food Technology Egusi offers many opportunities for the world's food technologists to help reduce African hunger. For one thing, it could become a protein source in many processed foods as well as a supplement to cereal- and root-based staples. Such extended use will depend on the knowledge of its chemical properties, nutritional properties, and functional properties, such as those relating to thickening, stabilizing, and fortifying processed products. All of these await further elucidation.

In addition, the seed-extraction methods need updating. To produce egusi on any scale, you cannot rely on rotting away the pulp of billions of fruits. One approach would be to find uses for the flesh that is now wasted. Perhaps there are animals that will eat the intensely bitter material, but a more promising line of research would be to investigate the bitter compounds themselves. Even now, there's a demand for compounds for "bittering" consumer products and thereby deterring children from accidental poisonings. A natural product like this could perhaps have a marketplace advantage big enough to overcome the limitations of distance and doubt. Concentrated egusi-fruit-extract could even prove more profitable in international trade than egusi seed.

Another pressing need is mechanical shelling. Again, the crop cannot expand dramatically if all the seed must be shelled by hand. Clearly, people cannot deal with billions of seeds using their fingers. This operation is probably not too difficult to mechanize, given that pumpkin seeds are already treated this way on a large scale.[13]

Nutritional Research Egusi seed comes in various types, and there is a crying need for critical studies of the variation in lipid and amino acid components between them. The parallel relation between the species' genetic diversity and protein quality also needs to be better understood.

[12] He also reports: "It does not form gas and the school children who have tasted it have not complained of any problems."

[13] John Cherry reports that a Bauer Mill with special teeth crack the shell and spit out the kernel with about 90 percent efficiency. There is, he says, no change in the color or texture of the resulting egusi flour.

Horticultural Development Like vegetables highlighted in other chapters, egusi presents agronomists, plant pathologists, crop breeders, and more with the chance to confront a new crop, to apply first principles, and to develop a baseline of technical knowledge that presently does not exist. Research challenges will be exposed on every side, however, a few of the things clearly needing investigation include:

- *Floral biology*. Though considered taxonomically just another watermelon, there are questions whether the plant is strictly monoecious, or perhaps occasionally dioecious, or mixtures of both? What are the most effective routes to pollination?
- *Germplasm*. The species' biodiversity needs to be gathered, conserved, and compared.
- *Varietal selections*. Elite types need development. Extra-large seeded types are one good target.
- *Agronomic details*. The optimal and minimal agronomic requirements should be better understood.
- *Yield*. There is a crying need for critical studies of how to achieve the greatest productivity. This may involve increasing the number of fruits per plant, the number of seeds per fruit, and/or speeding up the maturity time.
- *Edaphic effects*. Tests of the plant's ability to restore fertility and rehabilitate soil need to be run.
- *Crop limits*. The crop's limits also deserve testing. Is the egusi plant productive at high elevation? Under high rainfall? How about cool conditions? Scorching ones? What are its susceptibilities to disease and insects? Are there differences among individuals in such adaptabilities?
- *Acid soils*. This is one special limit deserving attention. Given its closeness to watermelon (which tolerates acidity as extreme as pH 5), egusi should be excellent for areas suffering from the burden of laterite, the red, mostly barren, acid soil that dominates many tropical regions.

Extend Egusi Beyond West Africa This would be a good time to test this crop in research studies across Central Africa, East Africa, the Horn of Africa, and southern Africa. *Citrullus lanatus* and *Lagenaria* species are well known in West, Central, East and Southern Africa and even in North Africa, but their usage varies from region to region. Some authors indicated that *Citrullus lanatus* originated from more than just the Kalahari Desert and surrounding areas. They include the southern Sahelian zones and neighboring savannas and arid areas.

Trials Beyond Africa Most nations now produce cucurbits—notably, watermelon, pumpkin, squash, and melon. The egusi plant is likely to grow well for them, too. People in the former Soviet Union commonly snack on pumpkin, sunflower, and similar seeds. Could egusi become a Russian or

Ukrainian crop? Maybe. The giant size of the seeds would be a good incentive. In addition, the plant might thrive in the Central Asian republics, whose aridity makes many crops difficult to grow.

It is worth getting egusi samples, using proper protocols, into the research programs on those related crops all over the world. Those specialists with lifetimes of experience with related cucurbits are likely to possess deep insights that can boost egusi and help Africa's food production right away.

Special Research Challenges A number of technological developments could help. These include:

- *Mechanical processing*. Post harvest handling constitutes a serious constraint for the production of egusi. Currently, a lot of labor and water are required to process the seeds. In addition, continual sunshine and clean drying areas are vital, because if the seed starts germinating its value plummets. Developing appropriate technologies or tools will do more than almost anything to boost this crop.
- *Dehulling*. In particular, a machine that facilitates the laborious extraction of egusi kernels will increase production almost beyond measure.
- *Hull-less types*. A diligent search may turn up "naked" egusi seeds (counterparts to those found in pumpkin). This would mean that people would not have to shell the seeds, which would save countless days of drudgery.[14]
- *Fuel*. Research should be undertaken to explore the possibility of sun-drying egusi roots and burning them. The roots are very large and, like those of other cucurbits, they dry to form a hard, wood-like material that makes good fuel for cooking stoves. In the semiarid zones, where egusi grows, sun is plentiful but fuel is difficult or impossible to obtain. Egusi-root could perhaps become a major fuel for the Sahel, which has been largely denuded by wood-gatherers.[15]

Taxonomic Clarification Is egusi really an aberrant watermelon? Perhaps this is a case where conventional taxonomy is inadequate for determining differences in the DNA. The flower structure may resemble a watermelon's and they can be interbred (though we heard no reports of "cross-contamination" being a problem in the field), but the two plant types are obviously not genetically identical.[16] Their other parts look quite distinct,

[14] However, hull-less seeds might not survive the current method of extraction by rotting the fruits and would require a different mode of seed extraction from the traditional one.
[15] Information on cucurbit-root fuel from Gene Schultz.
[16] Through crossing trials, USDA researchers have found the characteristic fleshy pericarp of egusi seed may be controlled by mutation in a single recessive gene (which they term *eg*) in "normal" watermelons (Gusmini, G., T.C. Wehner, and R.L. Jarret.

and the two seem to come from different areas of Africa.[17] Modern technologies, such as DNA fingerprinting and cross-pollination trials under rigorous laboratory conditions, are needed to clarify whether egusi is an inedible watermelon or a distinct species.

As has been mentioned, the egusi seed seen in the markets actually comes from a variety of species, depending on the location and season. So, follow-up may actually expose a cluster of climbing, crawling, trailing, and creeping herbaceous plants with both individual and common promise—all of them masquerading under the name egusi.

SPECIES INFORMATION

Botanical Name *Citrullus lanatus* (Thunb.) Matsum. & Nakai var. *lanatus*

Synonyms The disagreement on egusi nomenclature is such that the botanical name is variously given as:

- *Citrullus vulgaris* Schrader (also watermelon)
- *Citrullus vulgaris* Eckl. and Zeyh. (also watermelon)
- *Citrullus lanatus* Thunb. (also watermelon)
- *Citrullus lanatus* (Thunb.) Mansf. (also watermelon?)
- *Colocynthis citrullus* (L.) Kuntze.
- *Colocynthis citrullus* Linnaeus

Family Cucurbitaceae, Gourd Family

Common Names

English: edible-seed melon, white-seeded melon
French: ononde, graines d'quonde, "sesame"
Fon: Goussi
Fulani: denne nai
Ghana: neri, niri
Nigeria: egusi, guna shanu (Hausa); denne nai (Fulani); ibara, bara, ito (Yoruba)
Spanish: calabaza pamué
Sudan: surat

2004. Inheritance of Egusi Seed Type in Watermelon. *Journal of Heredity* 95(3):268-270). Although "egusi" consists of a suite of other differences (such as dry, bitter flesh), and regardless whether one species or two, this discovery could open a door where the world of research understanding about watermelon could be confidently applied to egusi, and could also lead to new types of melons and seeds throughout the curcurbits.

[17] Both egusi and the watermelon are of African origin, but watermelon is native to the deserts of southern Africa and (given its present distribution) egusi seems to have arisen in West Africa.

Description

The egusi plant is a vine with a non-climbing creeping habit. Its leaves are deeply lobed and blue-gray in color. The pinnately dissected leaves are alternately arranged. They are glabrous or slightly scabrid, denticulate and about 24 cm long. The flowers are monoecious, solitary in axils yellow and measure 13-20 cm in diameter. The yellow-green fruits are about the size of a melon, reaching about 18 cm in length. Their skin is often shiny; the flesh white.[18]

The seeds are numerous, white, smooth, flattened, and narrow. Most are larger than watermelon seeds, but they vary in size and thickness. Basically, they come in three separate forms: small, medium, and large. They also vary in the texture of the seed coat, which may be thin, thick, or encrusted in bumps. And the thickness of the edges varies from flat to molded. About half the weight of the seed is in the hull.

Distribution

Within Africa The exact extent of egusi cultivation within tropical West Africa has not been determined. Likely, it stretches from Senegal to Sudan and perhaps as far south as Congo. Major egusi-growing nations include: Mali, Burkina Faso, Togo, Ghana, Côte d'Ivoire, Benin, Nigeria, and Cameroon.

Beyond Africa The crop exists outside Africa, but its uses vary and are little-documented.

Horticultural Varieties

Several varieties of egusi exist in Ghana, Benin and Nigeria. They vary in color or size of the fruit and the seed.

Environmental Requirements

So little has been reported about egusi that we here rely largely on the cultivation conditions reported for watermelon. (See Horticulture)

Rainfall Although drought-tolerant, the plant requires a steady supply of water for best fruit production. It needs only a small amount of rainfall (250-500 mm) for survival, since their deep root system efficiently exploits available soil moisture. Excessive rainfall and relative humidity reduce flowering, and encourage development of leaf diseases. Waterlogging kills the plant.

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[18] For a full treatment of melon, see companion volume on the lost fruits of Africa.

Altitude Watermelons grow well up to 1,000 m in the subtropics, and may reach 1,500 m above sea level at tropical latitudes. Egusi probably acts similarly.

Low Temperature Watermelon requires a relatively long, hot, growing season (usually about 4 months of frost-free weather). For the seeds to germinate, the soil temperature at 5 cm depth must be at least 15°C. For growing watermelon the optimum temperature range is 23-27°C. Growth stops below about 18°C and the plant is very susceptible to frost. This limits production in regions with cool summers.

High Temperature Excessively high temperatures (over 30°C) during blooming may be harmful, reducing fertilization of the flowers. But such heat does not kill the plant. The wild melons in the southern African deserts grow where the temperature is often 36°C or more. Plants will tolerate even higher temperatures for short periods of time.

Soil Not unexpectedly, egusi yields are best on fertile humus-rich loose soil. It also grows successfully on soil of low fertility. Soil depth should be at least 10 cm. Watermelon tolerates not only acidity, but also alkalinity (up to pH 8.0); the optimum pH range, however, is 5.5-7.0.

Related Species

Egusi-ito[19] is a crop so similar to egusi that much of what has been said above can be applied to it as well. The plant is even less well known, it grows in wetter, more humid locations, and is a climber that is often grown up over the roofs of village houses. It is also often cultivated close to small trees and shrubs, fences, or similar support.

This white-seeded melon is grown mostly in Western Nigeria and Cameroon as an oilseed crop. Its oil is considered superior to that of peanut, and it sells for higher prices in the market. It is also a source of protein. It has been described as a species of immense potential as a new crop for the tropics and deserving of further investigation.

Botanically speaking, egusi-ito is a monoecious, partially drought-resistant curcurbit. The fruit may be up to 30 cm long and 10 cm in diameter. It contains numerous quite large seeds each of which may be up to 2 cm long. They are used like the seeds of egusi. In some parts of eastern Nigeria, the leaves are wrapped around fresh cornmeal and winged termites, cooked, and then eaten as a delicacy, mostly by women and children.

This plant is more promising than egusi at low elevations in moderately high rainfall areas.

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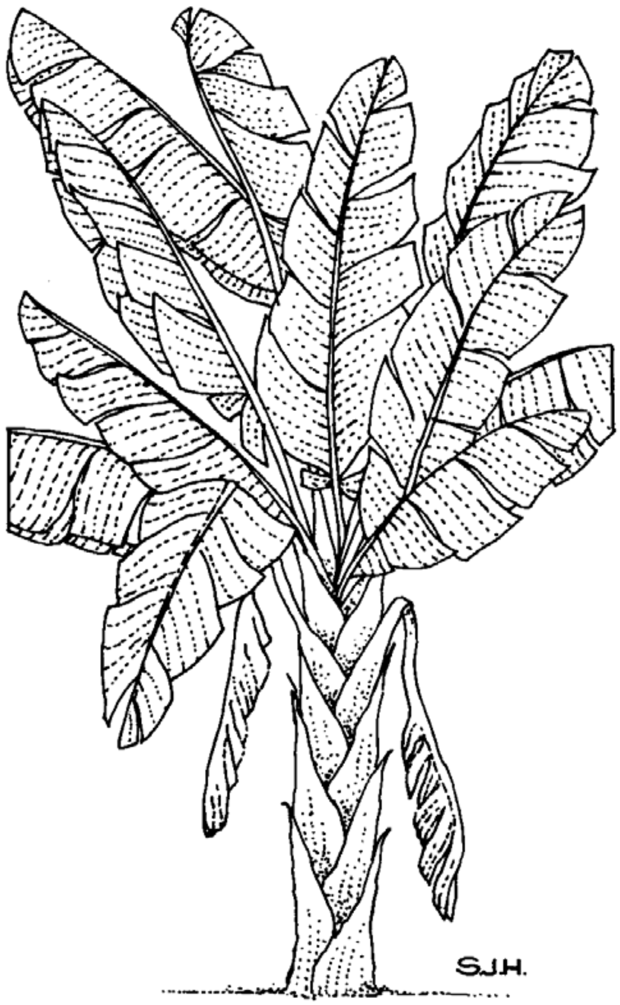
[19] *Cucumeropsis mannii* or *Cucumeropsis edulis*.

More Relatives

As noted, the "egusi seeds" in the markets may in fact derive from several species. The Gourd Family, to which egusi belongs, is represented in Nigeria by 21 genera and 41 species. Most are wild but a number are cultivated. Little-investigated relatives of economic importance include *Coccinia barteri* and several species of *Cucumis*, *Zehneria*, and *Momordica*.



Ensete ventricosum

9

ENSET

When drought struck Ethiopia in 1984 and 1985 a horrific tragedy unfolded as the food crops millions depended upon slowly succumbed. The horror was made all the more memorable because it unfolded before the eyes of the world, as television beamed the scene into households from Germany to Japan to Australia. Few viewers had ever witnessed in real time the specter of walking skeletons, children with bellies swollen as if pregnant, babies dying at their mother's breast. The images shocked the common conscience. They still do. "The world has seen a lot of suffering," said U.S. congressman Tony P. Hall, "but we still judge hunger against the depths of Ethiopia's hell."

Among the millions of sufferers were southwestern Ethiopia's Sombo people, who relied on cereals for their very existence. In the mid-1980s their fields of tef, sorghum, and maize produced little or nothing. Faced with empty shelves and empty stomachs, the Sombo decamped en masse. From their villages in Ilubabor Province they headed eastward, some trudging as far as 500 km to Woliso, a town hardly 100 km short of Addis Ababa itself. On this long and painful trek many died, but in the green highlands the survivors discovered a wholly new type of food resource, a vegetable taller than a house. During their enforced exile in that salubrious region so close to the great capital, they taught themselves to cultivate this huge herb. Returning to Sombo, they carried planting materials home, and the alien food grew to be part of their everyday diet. Already that has paid off. In 1992, a year of constant downpours, most of the coffee crop and up to 90 percent of the cereal crop succumbed to disease. This time, though, there was no famine and no trek in search of succor…the Sombos lived off their gigantic vegetable. Then, in the year 2000 drought again afflicted Ethiopia. By now the new food was well and truly grounded in the Sombo soil and culture. Once more, the suffering caused by empty shelves and long marches never arose.[1]

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[1] This story and much of this chapter's detail come from *The Tree Against Hunger*., posted at www.aaas.org/international/africa/enset. We are grateful for the authors providing so much information, much of it effortlessly via the worldwide web—a clear example of its broadcasting power; perhaps no other lost African crop has so quickly

This is far from being an isolated story. Although almost no outsiders have ever heard of it, this tree-like herb, perhaps the biggest of all vegetables, underpins much of the food supply in Ethiopia's highlands. Production is concentrated mainly in the areas south and west of the capital, but farmers in the central and northern stretches grow it too (mainly as an "ornamental crop" and to use the leaves for various purposes, but even here the plants serve as a living food depot).[2] In terms of production this is hardly a small crop; all in all, an estimated 10 million people consume it. The harvest probably amounts to 2 million tons a year, a quantity surpassing that of radish, parsnip, horseradish, and other better known and much better supported crops.

This species, known as enset [en-SET], is unlike any other food plant. Sure, it looks like a banana—thick-stemmed, erect, and towering over the land—but its fruits are all but inedible. In this case, the food is formed inside the stem. The largest specimens have a trunk a meter in diameter and 10 meters tall, and its uppermost portion, which can be three meters long, is filled with starchy pith. A second major food is found underground. This so-called corm may itself be almost a meter long and almost a meter in diameter, and it is packed with starch like some giant potato.

An individual plant producing food by the cubic meter is something of a marvel. This long-lived species represents a standing food supply, available for daily use or for the rare times when all other eatables fall short. But enset's importance extends far beyond food. Every part is useful for something. Southern-highlands farmers declare that, "enset is our food, our clothes, our beds, our houses, our cattle feed, and our plates." In other words, this is a crop of life; like coconut it provides a basis for subsistence culture…a fundamental resource for those whom even buying bare necessities is more a dream that a prospect.

Although only a glance is needed to see enset's importance for poor-people's food security, deeper investigation is needed to plumb its true value. Interviews with farmers suggest that Ethiopian peoples who depend on the plant have NEVER suffered famine.[3] According to eyewitness reports, only the edges of the older leaves and the sheath surrounding the inner leaves were affected during the 1980s drought years, and once the rains returned the plants resumed growing as if nothing untoward had occurred.

In a sense, it seems surprising enset isn't more widely known. The rural locations that rely on it are some of the most densely populated in Ethiopia,

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enjoyed such exemplar service in this emerging global medium.

[2] This northern arm of enset cultivation extends to Lake Tana, the Simien Mountains, and even Adigrat near the Eritrean border.

[3] Different ethnic groups use enset in different ways, but the main ones using it for food are the Gurage, Sidama, Gamo, Hadiya, and Wolayta.

Gurage Zone, southern Ethiopia. The plant is perhaps the biggest vegetable of all and looks like a banana "tree." The food, however, comes mainly from the lower trunk, filled with starchy pith, which on the largest specimens can be a meter in diameter and three meters tall. A second food comes from underground, where a corm may be almost a meter long and a meter in diameter, packed with starch like some giant potato. Any plant producing food by the cubic meter is surely something to put to use in a hungry continent, but so far enset is barely known to science, let alone to Ethiopia's neighbors. (Jürgen Bierwirth)

if not the world. What seem from a distance like fields for food production can be as crowded as a suburb in a city, commonly containing 200 to more than 400 persons per square kilometer. In fact, more families are squeezing in daily, and as the farms shrink to accommodate them, more and more enset is being grown. Any species that allows this sort of concertina contraction of the farmland would seem like a godsend for a crowded world. Indeed, this giant vegetable produces such huge amounts of food that a single plant supplies a family of five or six for a month. Although perhaps said with exaggeration, a family of five supposedly can feed itself forever from an enset field less than 10 m by 10 m.

You might think that such productivity would demand meticulous care of the land. But, surprisingly, enset farmers do little to maintain or improve their plots, other than add manure. Although traditionally they incorporated exceptional quantities of animal waste, it is still fair to say that the plant provides a long-term sustainable food supply with minimal inputs—an ability one writer considers "probably the most noteworthy characteristic of the enset plant."

Also you might think that withholding inputs would hurt the land, which was far from fruitful in the first place. But that seems not to be the case either. Areas under enset actually appear to be in better shape than those around them…more fertility, more capacity to hold water, more organic matter, more tilth. Enset's perennial leaf canopy as well as its abundant production of long-lived leaf litter reduces soil erosion and retards the vaporization of organic matter under the triple goads of tropical heat, tropical humidity, and tropical microbial action. It is said that many enset fields have been in continuous production for decades, if not centuries, and yet remain productive, stable, reliable.

As to enset foods, they are not the most nutritious—not by a long shot. For all that, though, they are not meritless. Traditionally considered fit only for impoverished farmers, they are now attracting the interest of the better off. Throughout Ethiopia the historical perception of enset as mere "peasant fare" is breaking down. Fine diners who formerly wouldn't be seen over a plate of enset enjera[4] now demand it. And a fermented enset extract called kocho has become extremely popular in Addis Ababa, even in upscale restaurants.

Although this plant comes with many telling positives, it comes with telling negatives too. For one thing, enset produces food slowly; after planting, the really large quantities of food in the upper part of the plant can take 7 years to develop fully. For another, neither the stem's starchy pith nor the corm's potato-like pulp is well balanced, nutritionally speaking. For a

[4] Enjera is Ethiopia's staple, a spongy pancake-like bread wholly unlike anything else in the world. The dough, which like sour-dough is fermented before cooking, normally comes from cereal grains, especially from the tiny seeds of Ethiopia's own tef (*Eragrostis tef*). For details, see tef chapter in *Lost Crops of Africa. Volume 1: Grains*.

third, the planting materials are difficult to produce. Fourth, this clonal crop is quite vulnerable to several diseases. Finally, extracting enset starch is one of the most laborious tasks in all agriculture. Sweatshop labor in the cities seems a breeze compared with the "sweat-plot" tyranny enset fields impose.

PROSPECTS

It has been said that, "the main function of vegetables in semiarid areas should be to provide a means of survival in case of failure or partial failure of the staple cereals, which are more vulnerable to drought and insect attack." If this be true, then enset would seem the ideal candidate for famine insurance. Yet this enigmatic vegetable is a food resource in only one country, a fact indicating that it may not travel well, no matter what its promise. Ethiopia's neighbors, often beset by their own horrific droughts and famines, do not grow enset. Not even Ethiopians living in northern and eastern parts of the country seem particularly attracted to it. This may be due to the peculiar production, processing, and consumption characteristics of the plant. Enset is a perennial crop that needs 4 to 8 years to reach full maturity. The complex and arduous processing of its products requires special skill, tradition, and patience. And it is often not an instant hit with consumers. One needs time to begin to like enset food.

Within Africa

Although it might not find new countries to conquer, enset could certainly expand within Ethiopia. Apparently, it was eaten over a far greater area until just a century ago when it was abandoned and forgotten, perhaps due to misguided colonial influence.[5]

Beyond Africa

The plant seems to have no difficulty growing in lands beyond the seas and (at least in principle) Ethiopian immigrants in Israel and parts of the United States might try cultivating it. However, it seems unlikely that enset will ever make it onto the crop-production lists in any non-African nation. The immigrants are overwhelmingly from central and northern Ethiopia where enset as a food is unknown. And getting the plant to produce food takes time, and perhaps tradition.

USES

[5] Sadly, this lapse had fateful consequences. "The northern town of Lalibela, famous for its eleventh century rock-hewn churches, is also the site where thousands of people died as a result of the mid-1980s famine," write *The Tree Against Hunger* authors. "Some farmers in Lalibela grow a few enset plants near their houses in order to use the leaves to wrap bread for baking. Like other northern Ethiopian farmers, those farmers [we] contacted had no knowledge of enset as food."

Possibly no plant on earth can match this one for the number of products it provides poor people.

Greens When young and succulent, several enset parts can be boiled like cabbage or artichoke. The giant stem is actually fashioned out of overlapping layers of rolled up leaves, and the thick immature leaf stalks are cut into small pieces, boiled, and reportedly come out tasting like cooked celery. In addition, the immature pith can be extracted from inside the stem and boiled as a vegetable.

Flour The best quality enset food comes mainly from the stems of mature plants. The milky white pulp, known as bula, is obtained by laboriously scraping it off the inner leaf tissues. Most is eaten with milk in the form of an acidic porridge, which is considered a status food. Squeezing bula produces a milky liquid that can be concentrated and dried into a white powder. Dough made from this starch-filled flour is turned into many things, including enjera, porridge, and dumplings.

"Cheese" Whereas the whitest and cleanest pith samples are made into flour, the rest are put aside to ferment. Typically, the pasty pulp is placed in a deep pit and left for a few weeks or months. What emerges is a doughlike material called kocho, which, like a great cheddar, keeps for months or years without spoiling. More than 20 foods—yogurts, cakes, dumplings, porridges, and so forth—are made from it. Commonly, kocho is mixed with spices and butter. Some is chopped small and cooked with meat and cabbage. It is so useful and popular that many farmers have dug the fermentation pits inside their homes to foil thieves.

"Potato" Young enset corms are commonly cut up and cooked like potato, yam, or cassava. They can also be grated and added to the stem pith to form flour and kocho, as mentioned above.

Leaves Banana leaves are certainly big, but enset's are bigger. Up to five meters long and nearly a meter wide, they are employed as a sort of natural wrapper for bread, grain, meat, kocho, and many more foods. Practically everything leaving the village for the market goes wrapped this way. These huge flat sheets of vegetation also line the kocho pits. Moreover, dried leaves are commonly pulped to make cleaning rags, brushes, baby cushions, diapers, and trivets for supporting hot cooking pots. They are woven into baskets, mats, rain capes, and hats. Some are used as plates for serving food on special occasions and much of the enset leaf crop becomes bedding for man and beast.

Beyond all that, the giant green fronds are an important feedstuff, especially in the dry season when grasses tend to make themselves scarce.

Enset leaves are customarily hauled into the house to satisfy the cattle stalled there nightly for safety and for warmth.

The round and hollow stems (petioles) and woody midribs of these giant leaves are separated from the flat leaf tissue and burned as fuel, woven into mats, and made into other materials useful around the house. Insulation between layers of roof thatch is one example. Water pipes is another.

Fiber The process of separating the flour from the crude pulp yields a special byproduct: a strong threadlike material not unlike abaca. A world-renowned fiber (from another banana relative, in Asia), abaca withstands boiling water and has proven invaluable for making the tea bags now used worldwide. Each year Ethiopia's factories process about 600 tons of the enset counterpart, turning it into cordage, sacking, bags, ropes, mats, construction materials, and clothes.

Nurse Crop Enset is most commonly grown around houses. There, the plantation acts like a personalized forest, sheltering the family members, their plants, and their animals from wind and sun. Encompassing the homestead with a continuous canopy of vegetation is the goal of most growers. In fact, farmers go out of their way to get the canopy to close up quickly. Not incidentally, this provides an ecosystem conducive to the production of such things as garden greens and coffee. Farmers commonly plant sun-loving annuals such as maize and cabbage among younger enset plants, taking advantage of the sunlight before the canopy closes. But mostly they grow a range of shade-requiring species.

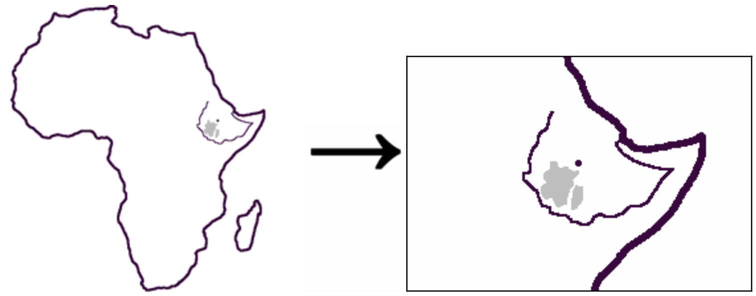
Ornamental With its thick, dark-green foliage, enset not only appeals to those living among it, but from a distance it provides an attractive patina to the Ethiopian landscape.

NUTRITION

Like cassava, sago, plantain, and some other staples, enset flour is little more than starch, with minimal fat, protein, vitamins. Each kilogram contains a mere 37 grams of protein. Enset-based diets thus need heavy supplementation. However, at least one mineral occurs in reasonable quantities: The calcium content is said to be higher than that of other roots and tubers.

Fermentation increases protein content and slightly raises the levels of essential amino acid. Indeed, the fermented pulp is said to contain more lysine than cereals have, but the methionine content remains low.

Despite the plant's dismal nutritional power, something about the household garden system benefits human health. In the 1990s a total of 6,636 children from four of Ethiopia's ecological zones were examined for signs of the blindness brought on by vitamin A deficiency. Sadly, beta-



General area of enset cultivation southwest of Addis Ababa (locations and boundaries approximate). Wild enset ranges from Sudan to Nigeria to South Africa. Although few outsiders have ever heard of it, this tree-like crop underpins the food supply in Ethiopia's densely populated southern highlands, where an estimated 10 million people consume it annually. (Map based on *Tree Against Hunger*, courtesy of AAAS.)

carotene levels were deficient in 10.4 percent of the children and low in 26.4 percent. A more unexpected finding, however, was that children from the enset zone had the highest beta-carotene concentrations of all. In their conclusion the researchers recommended that Ethiopia initiate a vitamin A deficiency control program, with the main emphasis being placed OUTSIDE the enset zone.

HORTICULTURE

Cultural practices vary between different localities, but virtually all enset is produced in small plots around the homestead. Compared to other crops the production involves many complex steps.

Planting is one of the most complex steps. Enset is propagated not by seed but by vegetative means. Trouble is, the plant has no vegetative part to use. However, in what is probably the key to the crop, ancient Ethiopians discovered that cutting out all the central tissue induces the smooth corm to burst out in buds. To bring this about, the farmer cuts the top off a young plant, slices out the corm's center, and packs soil and manure into the hole.[6] With its "heart" excised, the corm has no way to replace its leaves and flower stalk and, in a last-ditch attempt to reproduce it throws off as many as 200 buds around its edges. After a year, those buds sprout leaves and can be broken off. The resulting suckers, looking like ensets in a bonsai garden, are planted in nurseries, where, following another year or two, they turn into

[6] Because of dominance by this apical bud, lateral buds on the true stem do not usually develop; but once the apical bud is removed, these lateral buds form suckers around the periphery of the mother corm piece.

viable plants with all the size and qualities of their parent.

Managing the crop in the field is a second complex step. Again almost every locality has its own variant, but one common feature is a strange sort of "shifting cultivation" in which the plants are moved around like men on a chessboard. This seems to be an attempt to keep a canopy of leaves always sheltering the garden as well as to keep the bigger specimens from cannibalizing each other's nutrients and water. Some individual plants get moved once in their lifetime; others shift positions up to four times, at ever-wider spacing.

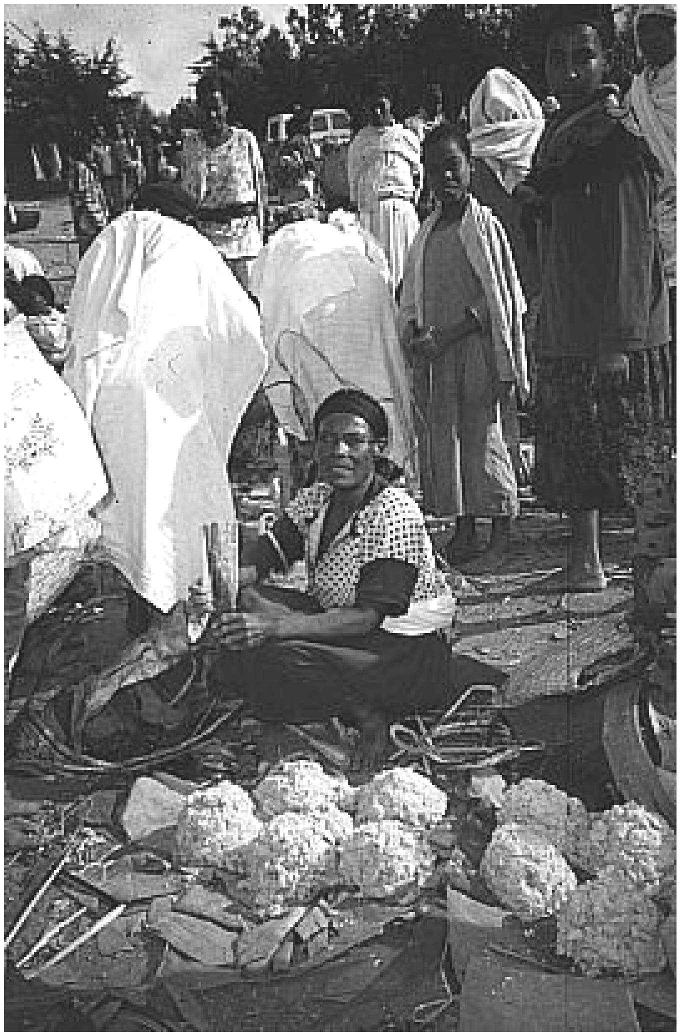
Harvesting is complex too. Some plants get cut down after two or three years (for the fresh corms); others are left for perhaps three times as long to generate the maximum amount of stem starch. All this variation in production allows the family to have a continuous food supply for years, if not forever. To outsiders used to the order of grain fields in places such as Kansas or New South Wales, however, it seems like a scene from some nightmare of cultivation chaos.

HARVESTING AND HANDLING

Although we've said that enset plants typically live 7 years, the lifespan depends on the altitude. In warm locations at low elevation ensets reach maturity in five, four, or even three years. In colder higher locations they can take ten or fifteen years. Once mature, the plants must be harvested because they then begin flowering, use up all the starch they've stored, and die.

Although the farmer normally harvests the plant just before it flowers and dies, it may be harvested anytime during the years the starch is building up in the stem and root. This is where the backbreaking labor comes in. The farmer cuts the pulp-filled stem or corm into strips using something like a machete, then scrapes out the pulp and juice using small bits of wood or bamboo. The task seems never-ending because each pass scrapes only a small sliver from the fibrous pulp.

Yields are difficult to evaluate because different plants are grown for different numbers of years, their spacing changes with time, and at various points they are interspersed with other species and other-sized enset plants. However, it has been estimated that the average family cultivates between 200 and 400 ensets in their household garden, consuming 10 to 20 per person per year. A normal-size mature plant is said to give 26 to 42 kg of food. In regions where enset is the staple crop, people consume 0.43 to 0.7 kg of kocho daily. According to those who recorded this fact, such an amount of kocho provides 860 to 1,400 calories, or between half and three-quarters of the food-energy typically consumed in rural Ethiopia.



A woman selling kocho at a local market. Note that enset leaves are used like plates or mats on which to display the product. Women are generally the exclusive marketers of enset food products. (Anita Spring)

LIMITATIONS

Diseases are collectively the most severe biological problem this crop faces. In several locations bacterial wilt is currently very threatening. It attacks right up to the moment the plants are ready to harvest. Nothing could be more mean sprited. The farmers become so devastated by the waste of

years of life, labor, and land that out of pure frustration they switch to crops that are less galling.

Enset is attacked also by root-knot nematodes, viruses, and fungi. During the early 1970s a fast-spreading fungus (*Fusarium oxysporum*) decimated enset and precipitated a famine. This fearsome fungus is related to others attacking bananas worldwide; luckily in this case the enset recovered.

Enset processing is an overall abhorrence. Not only is it tiresome and demoralizing, it is unhygienic. Someone has written that "without women to process enset, there would be no enset food produced and the plant would simply be an ornamental, as it is in other parts of Africa and Asia." That says a lot, and not just about the plant.

Lack of understanding is a big limitation as well. Until recent years the Ethiopian government emphasized more prestigious, profit-making, crops such as cereals. Only in 1997 was enset declared a National Crop, making it eligible for reasonable research and development funding.

NEXT STEPS

Following are a selection of possibilities that can move enset forward to better serve African needs.

Plant Health Bacterial wilt deserves top priority. On the surface, this bacterium should not be difficult to deal with. It is spread from plant to plant not by wind or water, but by the farmers themselves. Any object touching a contaminated plant or processed product (such as kocho) picks up the infection. Machetes and the little wooden scrapers are major culprits. Needed here is a public-health campaign aimed at making farmers keep their tools and plant materials clean of the infection. An especial need is to prevent the bacterium from spreading into the still uninfected regions. Another special need is to ensure that materials go to market only in wrappers untainted by wilt.

Beyond an education program there appear to be good possibilities for developing wilt-resistant enset plants. Already, some farmers have noted that certain clones tolerate the disease, while others revive rapidly after a bout with the bacterium.

Reducing Drudgery Several institutions have developed devices that reduce the tedium and time needed to process enset.[7] Few if any have had much impact. Women are beginning to use iron scrapers for decortication and cloth squeezers for bula, but there is still vast scope for reducing the damaging drudgery that devastates lives. Needed now is a concerted effort to develop and test:

[7] These include the Institute of Agricultural Research (at Nazaret and at Awassa), the Ministry of Agriculture, and Awassa College of Agriculture.

- a decorticater that separates pulp from the leaf-sheath;
- a pulverizer to grate the corm into fine pieces;
- a kneader to squeeze water from fermented kocho; and
- a shredder to chop the fiber in the fermented kocho.

Indeed, there is also potential for all such devices to be disseminated as part of a cottage-industry development package that updates and simplifies the entire process of enset production. Presumably, most of the devices would be manually operated, but the potential for mechanized processing by portable or village-based power-driven scrapers, pulverizers, kneaders, and shredders should not be overlooked. This whole area of development needs open-minded innovators from mechanical engineers to food technologists to tinkerers of the handyman subspecies.

Livestock In *The Tree Against Hunger*, the authors draw attention to the critical role livestock play in enset farming. Cattle provide many vital things: manure to make the trees grow, milk and meat to balance the diet, power for plowing, and cash for times of need. This connection is not well enough appreciated in high places. "All too often," say the authors, "researchers and extensionists ignore the importance of livestock in maintaining the productivity (and with respect to enset, the sustainability) of agricultural systems."

Thus one of the best sciences for bettering this plant's production may be animal science. The authors state that positive effects on enset cultivation systems would come from improving animal nutrition and health, improving breeds, training farmers to cull herds, and providing information, capital, and planting materials to improve pastures and forages. The farmers seem likely to be very receptive. Even now, they commonly ask for better veterinary help.

Further, turning enset leaves into silage and feed concentrates has not been explored, but it could have great potential for enhancing feed for livestock.

Balancing the Diet Beyond raising the availability of milk and meat, the enset system's overall nutritional output could be improved by increasing the production of other vegetables. Grain legumes such as common bean, lentil, and chickpea have been suggested, but there must be many more possibilities. Although the thrust should be less toward research and more toward extension, there is vast scope here for far-reaching collaborations between nutritionists and horticulturists of many backgrounds.

Marketing Assistance Enset is a powerful tool for poverty reduction and prevention. Beyond being a subsistence resource, it is a commercial resource

of note. Thousands of women sell enset foods to make money for household supplies such as kerosene and salt. One "cursory survey" of the main Addis Ababa market, Mercato, revealed over 120 women selling kocho and bula. In addition, both women and men sell leaves, mats, rope, construction materials, and other non-food products made from the enset plant.

Informal interviews and observations at Addis Ababa restaurants indicate establishments often run out of quality kocho. They yearn for more. The shortages are blamed on poorly developed marketing and transport systems, but many related issues also need improvement, including storage facilities, quality assurance, capital, and packaging.

New Locations People in the regions of Tigray and Amhara (e.g., Gondar and Wollo) don't eat enset, but the plant occurs all around them, and they wrap dough in the leaves while baking their bread. Although attempts have been made to inform and encourage farmers here to grow the crop for food, more efforts are needed. Taken overall, enset could perhaps double in area, and prime locations for expansion are in these regions, which are vulnerable to droughts and disasters and where the plant occurs but is not used.

As far as locations outside Ethiopia are concerned, the crop might at first sight seem very promising. Wild enset already grows from Sudan in the north and Nigeria in the west, all the way to Angola and South Africa in the south. Nonetheless, its chances of being cultivated for food outside Ethiopia are probably slim. Not only are the methods of turning it into food unknown in those locations, they are probably difficult to introduce. Nonetheless, exploratory efforts are warranted. If the preliminary hurdles can be overcome, then this species might provide the long dreamed of stable, reliable, sustainable farming system much of drought-threatened Africa desperately needs. Its potential is mainly for areas that do well most years, only to suffer devastating periodic desiccation.

Food Technology There is a great need for food technologists to involve themselves with the problems surrounding enset. They are needed, for example, to make the processing hygenic and reliable. A starter (called gamacho) is used to begin the fermentation of kocho, but it is usually just a sample scooped out of the last batch. Partly for this reason, kocho is a variable foodstuff, not quite to be trusted. Food technologists should investigate this fermentation, create pure cultures, and adopt appropriate techniques from cheesemakers. In this way, quality kocho of verifiable safety and stability could be produced routinely. That will surely open up the big city markets.

Another role for food scientists is to identify the enset's nutritional components. For example, at present no one knows much about the protein's actual amino-acid profile.

Horticultural Development Although research on enset has sputtered along since at least the early 1960s, it has lacked continuity and direction. Thus, the door remains wide open to investigation on a dozen fronts. Examples provided by another reviewer include: the effects on growth and yield of different clones; plant spacing, and duration at a given spacing; transplanting methods; manure and/or fertilizer amendments; propagation techniques; and environmental conditions (i.e., temperature, water, and sunlight). All these have yet to be pinned down.

Much of what is needed is basic research. For instance, corm rot, sheath rot, and dead-heart leaf rot are all diseases for which the actual pathogen remains unidentified.

One special challenge is to speed up the plant's growth. The best time to harvest it is just when flowering begins, but exactly when flowering occurs depends upon climate, clone, and management. Currently, it varies from 3 to 15 years but is most commonly 6 or 7 years. A broad approach, involving everything from clone selection to field management could possibly cut that time in half and make the farmers all the happier, not to mention twice as safe from failure due to drought or disease.

SPECIES INFORMATION

Botanical Name *Ensete ventricosum* (Welw.) Cheesman

Synonyms *Musa ensete*, *Ensete edule*, *Musa ventricosum*

Family Musaceae

Common Names

Ethiopia: enset, guna-gunaf (Amhara), asat (Gurage), weise (Kambata), and wassa (Sidama), kocho (G), koda (Am/Sodo/Oromo), werke, wesa (Oromo), [*aquimi (Ari*)]
English: enset, ensete, Abyssinian banana, wild banana, false banana
Malawi: Chizuzu (Ch)
South Africa: Afirikaanse wilde-piesang (Afrikaans), motholo (Pedi), mulala (Venda)
Kenya: ndizi mwitu (Swahili), makulutui (Ka)
Zimbabwe: mubhanana mufigu, dzoro, hovha

Description

This species looks quite like a banana plant. Enset, however, is usually larger, its leaves more erect, and shaped somewhat more like a lance head. They are spirally arranged, and bright green with a striking red midrib.

What would appear to be the trunk in most plants is actually three distinct sections. A short length at ground level is the only part of the plant

that is true botanical stem. Leaf sheaths emerging from this core form a tightly wrapped pseudostem, at the top of which the leaves unfurl into the classic "banana" form. This stem-like portion, up to three meters long, contains both edible pulp and quality fiber. And below the soil line is an enlarged corm, up to 0.7 meters or more in length and diameter, also full of starches. A fibrous rooting system grows out from the corm. While banana plants naturally form suckers or clusters of plants at the base, enset plants do not.

This is a monocarpic plant. Like century plant and bamboo, it bears fruit only once, and then quickly dies of exhaustion. It may live 15 years before the big fat flower stalk emerges from the top of the plant. Once out, it forms a massive, pendulous spike. Surely one of the world's biggest flowers, it is 2 to 3m long, and hangs downward from a stalk in the center of the plant. The individual florets are cream colored, with a single petal, enclosed in large maroon bracts. The fruits resemble small bananas, having a yellow skin, but they are filled with a mass of hard, small pea-like seeds.

Distribution

Few details about enset's overall distribution are known.

Within Africa The wild type occurs from Nigeria in West Africa through the central to the southern parts of the continent, including Transvaal, Angola, Zimbabwe, Mozambique. However, Ethiopia is the only place where the species has been domesticated. Suggestions that the plant was tamed as far back as 10,000 years ago have been presented. The wild form occurs at lower altitudes than the present area of enset cultivation in Ethiopia.

Beyond Africa Enset is sometimes cultivated as an ornamental in Asia and other places. New Zealand is one country that it reportedly beautifies.

Horticultural Varieties

There are no formal varieties but farmers recognize more than 50 different clones, and normally grow several together in the same field. Certain ones are renowned for their quality corms.

Environmental Requirements

Detailed studies on the effects of environmental constraints such as temperature and water availability have not been conducted. Therefore, all claims as to enset's range of adaptation are suspect.

Rainfall Most enset-growing areas receive annual rainfall of between 1,100 and 1,500 mm, the majority of which falls between March and

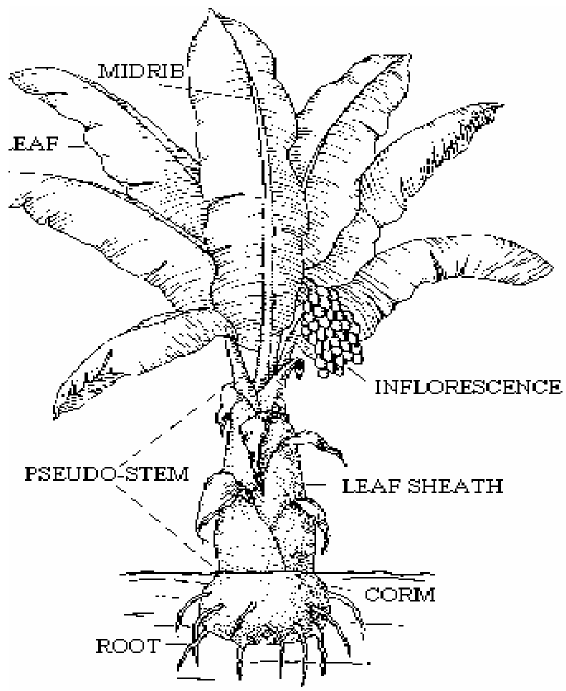
September. This amount may not be necessary, but it is known that the crop fails in consistently dry environments with short rainy seasons.

Altitude Enset is planted at altitudes ranging from 1,100 to more than 3,000 m. It is said to grow best between 2,000 and 2,750 m.

Low Temperature The average temperature of enset growing areas is between 10 and 21°C, with relative humidity of 63 to 80 percent. The optimal temperature range has been put at 18 to 28°C. From preliminary observations it can be said that enset cannot tolerate freezing. Frost damage on upper leaves is commonly observed above 2,800 m elevation, and serious stunting occurs above 3,000 m.

High Temperature Any constraint to enset plant growth probably is more related to available water than to heat. It is possible, however, that the crop is more subtropical than tropical because the current production areas—while close to the equator—are so high in the sky.

Soil Enset grows well in most soil types, as long as they are sufficiently fertile. Neither roots nor corms tolerate waterlogging for long. For that reason, the crop is usually grown in well-drained soils without high watertables. The ideal soil seems to be a moderately acidic to slightly alkaline (pH 5.6 to 7.3).


MIDRIB
LEAF
INFLORESCENCE
PSEUDO-STEM
LEAF SHEATH
CORM
ROOT


S.J.H.

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LABLAB

In parts of tropical Asia lablab is a popular, even important, food. For the rural population of southern India, for instance, this crop supplies a considerable proportion of the protein in the daily diet. Both there and in other regions of India young lablab pods are widely consumed as a vegetable—boiled like French beans, dumped into curries…things like that. Sometimes the immature seeds are extracted from the green pods and boiled or roasted for dinner.

And India is not the only tropical Asian nation to exploit lablab. Farther east, the mature seeds are treated like soybeans: boiled and processed into tofu or fermented into tempeh. The sprouts are said to compare in flavor and quality with those of mung bean. The leaves and flowers are consumed like spinach (most notably in a famous Indonesian dish that goes by the generalized name of "lablab"). And the seeds have been processed like soybean into a protein concentrate.

The strange thing about this nutritional cornucopia of Asia is that it is, by origin, African. Stranger still is the fact that the plant is almost unknown to the present-day inhabitants of its native continent. Whereas it certainly can be grown in almost all regions of Subsaharan Africa, lablab's use as a vegetable seems all but unknown and has not been pursued vigorously in any of them until, perhaps, recent years.

"Shameful" certainly seems to be the right word for this. The fact that little or no help is being provided this food plant in its home territory, where malnutrition is chronic, is more than distressing. Making the situation particularly ironic is the reality that this local counterpart of the soybean possesses qualities that could prove exceptionally valuable for Africa's rural development and environmental stability. Beyond being a prolific food producer, lablab thrives on relatively acid soil of low fertility and high aluminum toxicity. Its penetrating roots draw nourishment from deep below the surface. And this vigorous legume improves the land's nitrogen content through the action of the highly active beneficial bacteria residing in nodules on its roots.

Lablab is also suited to poor-people's needs. The plant is simple to establish and easy to manage under subsistence conditions. It gives high yields. It resists droughts that affect leguminous crops that farmers now

struggle to produce in tropical Africa. And, generally speaking, it stays green and productive well into—even all through—the dry season, a period in the monsoonal tropics when food is hard to come by and the possibility of hunger looms large.

Tropical botany publications typically describe lablab as being of "probable Asian origin." On the surface that seems correct; the plant certainly finds its greatest development in South Asia and Southeast Asia. However, the center of diversity of genus *Lablab* is Africa, so there should be little uncertainty over its ultimate biological birthplace. Indeed, lablab's wild ancestor is even now scattered across, and is clearly a native to, much of tropical Africa.[1] Sometime before history was recorded one or more observant souls came to appreciate the wild species' potential and hauled seed samples across the Indian Ocean. In its new Subcontinental home people seized on the plant and down the many centuries since then developed it as a garden crop.

Having being cultivated since ancient times those food types have now reached a high degree of development in Asia. They are the main focus of this chapter. It is time to bring those vegetables home again and put them to use in Africa itself.

However, in a parallel and relatively recent endeavor, non-food varieties of lablab have been selected and advanced as forage and green manure crops. These coarser, more robust, and less palatable types, are planted in various parts of the tropics—including parts of Africa—mainly to produce forage. As a result, forage specialists these days consider lablab among their most useful tools. Managers of coconut, rubber, and oil palm plantations revere the species also, knowing from long experience that it is one of the most valuable, trouble-free, and reliable of all leguminous herbs for suppressing weeds and rejuvenating worn out soils.

It should be understood that modern horticultural science has not entirely neglected lablab, at least outside Africa. In India, for example, a series of cultivated varieties (numbered Co-1 through Co-9) have been developed as green vegetable crops. One of them (Co-9) is said to average 7,500 kg of pods per hectare in the southern state of Tamil Nadu. It is quick maturing (120 days), with broad, flat pods, and an attractive light-green color as well as good flavor, aroma, and texture.

In Australia (notably, northern New South Wales and southern Queensland) another promising food variety is becoming quite widely used. 'Koala' is a short season, early maturing lablab, suitable for food (and fodder) production. Its developers claim that its white-to-cream colored

[1] One of Africa's most knowledgeable legume botanists leaves no doubt about the point: "*Lablab purpureus* is unquestionably of African origin," Bernard Verdcourt wrote to us some years back. "The only wild taxon known is subspecies *uncinatus*, which is very widespread in tropical Africa."

In Asia lablab is a popular foodstuff. For rural peoples of southern India, for instance, its pods and seeds supply much of the daily protein. The strange thing is that lablab is African. Stranger still is the fact that it is almost unknown to present-day Africa. Yet this local counterpart of the soybean possesses qualities that could prove exceptionally valuable for nutritional well-being, rural development, and environmental stability almost throughout its continent of origin. Glenn Kopp/Missouri Botanical PlantFinder mobot.org/gardeninghelp/plantfinder

grain is suitable even for export, and they dream of sending shiploads of it to Asia like a southern-hemisphere soybean. Commercial crops of 'Koala' have yielded up to 2 tons of grain per hectare (without irrigation but under otherwise good conditions). Trials show that on average it produces 20 percent more grain per hectare in subtropical Australia than does mung bean.

Beyond all its uses for food and fodder, the plant can be used advantageously to provide organic matter and fix soil nitrogen; thereby improving subsequent crop yields in a cheap and environmentally friendly manner. It is not inconceivable that it could become an essential part of certain sustainable farming systems.

Taken all round, lablab might seem not too far removed from some botanical diamond in the rough. And that appearance is not untrue. Moreover, it is remarkably adaptable and so useful that it can be employed without waiting for the ultimate benefits that will come from agronomic cutting and polishing.

PROSPECTS

There seems no reason why the refined kitchen-garden types as well as the coarse field types (not to mention specimens combining qualities of each) should not take off vigorously in Africa. Indeed, they could be employed widely and with due dispatch. At present, Africa does not use the vegetable type to any great degree, but the forage types are already there to provide a foundation for progress and understanding. Moreover, smallholder farmers are beginning to use legumes in rotations, and multipurpose legumes like lablab are promising for land restoration and sustainable agricultural systems in most parts of the continent.

Within Africa

Strains of lablab capable of thriving under the diversity of conditions occurring across most of Africa can be found but the more refined types for food use probably need to be selected for specific sites.

Humid Areas Excellent. The plant thrives under high heat and humidity. However, in hot, moist climates certain fungal diseases are a concern.

Dry Areas Excellent. A well-established lablab plant's root system often penetrates into water sources more than 2 m deep, permitting luxurious growth to persist long after the rains have ended and the surface soil is parched. For this reason, the crop can have a long production season and can provide food, fodder, and soil protection long after other herbaceous species have dried and died.[2]

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[2] A reviewer wrote: "Certainly they are drought tolerant, have good root depth and in my

Upland Areas Excellent. Lablab is already grown in the eastern African highlands. And in Zimbabwe it is doing very well at an altitude of 1,500m.[3]

Beyond Africa

Excellent. The plant is already widespread throughout the tropics, but it offers so many uses, so many varieties, and such wide adaptability that it has by no means reached its potential even in places like South India that know it best. The plant also has potential in subtropical and warm temperate regions worldwide, as has been demonstrated in eastern Australia in recent decades.

USES

Lablab can be put to so many overlapping uses that it is hard to summarize them clearly. A selection of examples follows:

Pods The young pods of the culinary type are popular vegetables in India, Indonesia, the Philippines, and elsewhere in the Asian tropics. They are eaten like green beans or snow peas.

Seeds In India the dried seeds are split like lentils and used in making dhal, the major protein source for millions of the populace. They are also sprouted, soaked in water, shelled, boiled, and smashed into a paste, which is fried with spices and used as a condiment. Dried seeds are also fed to livestock.

In Africa, lablab seeds are cooked in any of the ways commonly used for beans: boiled with maize, ground and fried, or added to soups. It is included in the traditional Kikuyu dish called imo, a mixture including such things as maize, beans, bananas, potatoes or green vegetables all boiled down into a tasty paste. In Egypt lablab seeds are sometimes substituted for broad beans in preparing the fried bean cake called tanniah.

Leaves The leaves are occasionally used as a potherb, although they are said to be less palatable and less popular than cowpea leaves.

Environmental Protection As mentioned, the field-type lablabs are effective for land restoration.[4] They can be grown alone, interplanted with field crops, or included in crop rotations. They make a good cover crop in

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work in Zimbabwe, are doing very very well in 800mm rainfall at 1500m."

[3] Information from Bruce Pengelly.

[4] Lablab is the green manure which is grown in rotation with cotton and sorghum in the Gezira in Sudan—Africa's biggest agricultural enterprise—and is the last crop in the rotation, after which the land is bare fallowed for a season.

With a crude-protein content of 20-28 percent, lablab seeds are worth considering in malnutrition prevention programs. In addition the amino acids are moderately well balanced, with an especially high lysine content, which means that they help balance out diets that are heavy on the staples. The seeds are also a good source of energy. (Lori Alden, *The Cook's Thesaurus*)

coffee and coconut plantations, fruit orchards, and more. They are often planted as a second crop in rice fields after the harvest of paddy. In each case, they may be grazed after the pods have been harvested for food.

Forage Lablab is so fast growing that grazing or haymaking can begin 7 to 10 weeks after sowing. The plant withstands severe cutting. Cattle, sheep, goats, and pigs eat it avidly. Fodder yields of 5 to 10 tons per hectare are said to be normal. Hay from the whole plant (if cut at a young, leafy stage) is nutritionally comparable to alfalfa, although somewhat less digestible. When chopped, the plant produces good silage. Incorporating living lablab into grass pastures improves the quality, palatability, and digestibility.

Other Uses Nurserymen in the United States sell lablab as an ornamental. Certain varieties of what they call "hyacinth bean" are renowned for their long, bright, showy, purple blossoms. In a very clever initiative, the Government of Guyana encourages city dwellers to grow ornamental varieties along fence lines to form hedges that provide protein for the family table as well as a pretty prospect for the passerby. It is notable that lablab is suited to urban use.

NUTRITION

Comparing the crude-protein contents of lablab and dried seeds of common legumes shows that, at 20-28 percent, lablab is exceptionally

nutritious. In addition, amino acids are moderately well balanced, with especially high lysine content (6-7 percent), which means that lablab seeds complement cereal diets well. However, methionine deficiency (0.65 percent in one count) is reported, so in this regard the protein profile is not perfect.

The seeds, in addition to contributing relatively good quality protein, are also a good source of energy. However, as with many other pulses, the lablab seed contains antinutritional factors, which must be taken into account (see later).

The leaves also are rich in protein (up to 28 percent) and, at least among legumes, they are one of the best sources of iron (155 mg per 100 g of leaves, dry weight). Whole-plant protein ranges from 14 to 22 percent, depending on the season and the lushness of the plants.

HORTICULTURE

The lablab plant looks somewhat like cowpea and can be grown in a like manner. Although in the tropics the plant persists two or three years (if well watered) it mostly acts as an annual. When grown for food, lablab is usually sown in rows, either alone or mixed with crops such as maize, beans, potatoes, peas, and bananas. Normally, the seeds are directly planted into the soil of the field, kitchen garden, or fence line where the crop will grow. Germination is rapid, but establishing a good stand requires continuous soil moisture. Typically, several seeds are sown in each hole and the seedlings are left unthinned. The resulting dense growth tends to suffocate weeds.

Lablab is sometimes sown together with annuals such as sorghum and cotton. It suppresses weeds, helps protect exposed land, and contributes food after the primary crop has been harvested. It is normally left to its own devices, although weeding during the establishment phase may be necessary. The climbing varieties often support themselves on the convenient stems of taller plants, such as maize or sorghum.

The growth period can vary from approximately 75 to 300 days. In India, Co-1 begins to bear pods approximately 60-65 days after sowing and continues for 90 to 100 days. Other improved cultivars such as Co-6, Co-7, and Co-8, which can be grown year-round, produce pods 60 days after sowing and continue up to 120 days in South India. Mature seeds are normally harvested 150 to 210 days after sowing, but this depends upon the cultivar and the season of sowing (i.e. daylength regime). In equable tropical climates and with good management the plant can yield continuously for two or three years if desired.

Lablab nodulates easily—either with its specific rhizobia or with the cowpea-type, which occurs widely in tropical soils.

Compared with cowpea, the plant is more resistant to root diseases and more productive. In fact, certain types reportedly produce twice the herbage of cowpea. However, lablab stems are stronger, more fibrous, and less palatable than their cowpea counterparts.

HARVESTING AND HANDLING

When grown as a vegetable the green pods are picked by hand when they reach a reasonable size, usually when the seeds are about three-quarters formed. The plants are subsequently picked at intervals of several days, the pods being cleaned, graded for size, and packed in baskets for hauling to market. In the heat of the tropics both the green pods and the immature beans have relatively short shelf lives. The average yield of green pods in India has been recorded as varying from 2.6 to 4.5 tons per hectare.

Species of the genus *Lablab* tend to hold their seeds; they are less likely to dehisce immediately on maturity than many other legumes. Thus shattering is not a huge problem, and when grown for seed, lablab can be mechanically harvested. After drying in the sun the mature pods are beaten (using sticks or machines) to separate the dried seeds.

When grown as a forage, lablab can provide both high seed yields *and* high biomass yields. In experimental trials in northern Australia, four accessions yielded over 4 tons of dry seed per hectare.[5] One of these, a commercially registered variety called ‘Highworth,’ consistently provides over 1.5 tons of seed per hectare in commercial cultivation as well as 5-11 tons (dry weight) of forage. The forage has a protein content up to 22 percent and production is fast. In Queensland, lablab pastures are ready for grazing 60 to 80 days after planting, and optimum stocking with cattle is about 1.5 animals per hectare.

LIMITATIONS

Despite resisting attacks from Mexican bean beetles and other insects that devastate common bean, lablab is not immune to pests. Insects of the leaves, pods, flowers, and soil have proven serious in northern Australia, for example. And in Africa the neat little holes drilled by bruchid beetles are often seen in lablab seed.

Similarly, although generally reported to be fairly resistant to disease, lablab is not immune from attack. Some cultivars, for instance, have proven susceptible to bean rust and fungal rot.

Root-knot nematodes also can afflict this crop, sometimes seriously. And, in some African areas, the parasitic weed striga sucks the plant’s juices and energy with as much gusto as on other crop species.

The mature seeds (especially dark-colored ones) must be boiled before eating. Like most soybeans, they contain a trypsin inhibitor that is broken down by heat as well as a cyanogenic glucoside that is leached out by the cooking water.

At least in theory a vigorous plant like this carries the possibility of invasiveness. However, there are no reports of serious problems in this

[5] Information supplied by Ian Wood.

regard. Indeed, lablab's palatability to cattle, goats, and other herbivores helps lessen the risk of it becoming a problem.

Lablab provides a very dense cover but not right on the surface of the soil. Beneath the canopy there is enough space for water to wash through and (especially on sloping land) cause erosion.

NEXT STEPS

Though moderately well known as a resource for tropical agricultural systems, lablab is far from being used to its full potential. For purposes of improving the situation specifically in Africa, one can conceive of many activities, including the following.

Africa-Wide Thrust Because of its many outstanding qualities, the plant is recommended for immediate use in tropical Africa as a pulse, green vegetable, green manure, and forage. This is worthy of a coordinated—or at least an international effort.

Farmer Survey From the start, it would be wise to identify who might grow lablab and why. It might take off not as a food crop but as a dual-purpose plant—for food-and-forage, perhaps, or food-and-soil fertility. Finding local preferences might best be achieved *with* farmers. The crop will be new to them but their ideas about preferred varieties and uses would come out as the research progresses.[6]

Also from the start it would be good to identify not only farming-system opportunities but also taste-testing components (leaves, pods, grain) and then evaluation of key types of plants for systems. Africa does not use the vegetable type to any great degree. But, as noted, the forage types are already there and smallholder farmers have begun using multipurpose legumes in rotations in recent years.

Seed Supply In many local African areas where lablab could be beneficial, there is no way people can get started for the sole reason there is no source of seed. Rural NGOs, companies, farmer organizations, and others involved in seed production and supply should adopt lablab. With this dual-purpose legume getting farmers to use the seed should not be a problem. What is needed is to identify the best seeds for the locality, get them farmer-tested, then encourage on-farm seed production and storage for subsequent seasons.

In a related vein, key work is needed to identify core seed collections. A

[6] A reviewer wrote: "Sometimes these trials are very illuminating. In South Africa, we thought farmers would like white or light seeded lablab varieties. Not so. They wanted dark varieties—not for taste, but because when cooked the white seeded lines turned to mush too easily."

The forms of lablab that have been developed as green vegetables are promising profit-makers, producing huge yields (up to 7.5 tons per hectare) of pods that look and taste good, and producing them quite quickly (4 months). In addition, the dry seeds are becoming commercially important in Australia, where it is claimed that they are even suitable for export, like some kind of southern-hemisphere soybean. (J.H. Wildin)

recent paper describes the available germplasm and its diversity.[7] One of the world's largest lablab-seed collections is at the International Livestock Centre in Addis Ababa. And a seed collection in Kenya was the source of the lablabs now widely used in Australia.

Sustainable-Agriculture Projects Now is the time to incorporate lablab into sustainable-agriculture projects Africa-wide. In particular, trials are needed to identify best varieties and best practices to use this legume in smallholder farmings systems. One example: integrating lablab within cereal-based systems such as maize or rice, which could reduce the need for inputs of inorganic fertilizer.

[7] Pengelly, B.C. and B.L Maass. 2001. *Lablab purpureus* (L.) Sweet–diversity, potential use and determination of a core collection of this multi-purpose tropical legume. *Genetic Resources and Crop Evolution* 48:261-272.

It should be recognized that legumes generally add little organic matter to soils. Their litter is broken down too easily and too quickly. In this regard, lablab is no exception. Nonetheless, trials are needed, and they should incorporate more than just this species. Mucuna, perennial soybean, jackbean, and other potential competitors should be included for comparison. Some will be better than lablab in some situations. Mucuna, for example, is less susceptible to insects than lablab, so in a humid environment it will probably be a better choice for producing green manure.

Demonstrations To overcome farmers' reluctance to adopt any new practice, demonstrations involving lablab should be established across Africa. These might well be established on farms, allowing select farmers to demonstrate and sell the resulting seeds to their neighbors. An alternative approach is to use participatory on-farm lablab research, focusing on agronomy and taste-tests for grain and vegetable use.

Horticultural Development Despite lablab's widespread occurrence, little agronomic improvement has been reported. There is need for research into genetics and breeding for faster-maturing varieties with better and more dependable yields as well as for improved resistance to pests and diseases. One target might be lablabs that mature their pods or seeds uniformly together, making them attractive for commercial harvest. Another target might be lablabs that mature over time, so as to supply pods and leaves to the family diet for weeks or months.

Of course, before embarking on plant improvement researchers should locate the types farmers have selected over the past 3,000 years. The diversity in the existing landraces is already remarkable.

Once seed types are selected, then research and testing of management practices, including fertilizer requirements, time of planting, and plant populations for specific products (seed, forage, hay, or green manure) should be done. The impact on soil nitrogen and soil organic matter should be included, too.

Forage We think that farmers will jump at the chance to grow lablab when they see how productive it is and how much their livestock love it. But in developing forage types, attention should be given to several special features: dry matter yield and its distribution through the year, palatability and feeding value, and compatibility as an intercrop with crop species to improve stover/lablab grazing quality.

Food Technology Research into the feeding value of the seeds for humans and livestock (not overlooking poultry and pigs) is also needed. Methods to reduce or remove the antinutrition factors, either by processing or by plant breeding, are needed. Such aspects as processing the seeds into

protein concentrates for livestock, poultry, and human foods, and the functional and chemical properties of the protein, similarly deserve attention.

Commercial Operations Although the lablab now finds its greatest use in small-scale agriculture, its potential for large-scale mechanized production of protein seems impressive. Lablab thrives in the monsoonal tropics, a region where soybean fares poorly. The 'Highworth' variety—which is grown in Australia but actually hails from Kenya—shows that the crop can be suited to mechanical harvesting and production. Research along these lines is needed for possible large-scale rural development projects.

Torture Tests Because of this extremely adaptable species' potential to help marginal environments, varieties should be further tested for their outer limits of tolerance to aridity as well as to acid-, alkaline-, saline-, high-alumina-, and nutrient-deficient soils. Production levels will fall off in such areas but the value to human life might nonetheless be all the greater.

SPECIES INFORMATION

Botanical Name *Lablab purpureus* (L.) Sweet

Synonyms *Dolichos lablab* L. and *Lablab niger* Medik[8].

Family Leguminoseae. Subfamily: Papilionoideae.

Common Names Almost every country (indeed every Indian province) uses a different common name. A few in widespread use are:

English: bonavist, chicharos, chink, Egyptian bean, Indian bean, hyacinth bean
India: seem, sim, pharao, val, anunula, ararai, chapprada, chikkudu, field bean, mochair, parta
East Africa: fiwi
Sudan: lubia bean, kashrengeig
Ethiopia: amora-guaya
Philippines: agaya, apikak, batao, hab
Indonesia: kerana
Thailand: tua nang
Malaysia: kara-karci
Myanmar: pegyi

[8] The literature contains at least 26 separate botanical names for what now seem to be different forms of this plant. Many articles published in recent decades use the names *Dolichos lablab* and *Lablab niger*.

Description

The wild germplasm seems to be always perennial, but over the past few thousand years the landraces have been selected to be mainly annuals. Thus, most lablab landraces today are true annuals, but they will perennate if their seed production is curtailed.

Varieties differ in many characteristics: The growth habit may be bunch, spreading, or climbing. The flowers may be white, purple, pink, or blue. The pods may be short and half-moon shaped or long and thin. The seeds, although usually brown or black, may be cream, white, red, or speckled. The pods contain 3 to 6 seeds and are up to 15 cm long. They are generally oblong, curved and flat, and have wavy margins and pronounced beaks. Each seed has a prominent white hilum.

The plant is vigorous and the climbing type can grow 5 to 6 m tall. In most varieties the inflorescence is an erect, long stalked raceme held high above the foliage.

Distribution

These days, lablab is found in warm regions worldwide.

Within Africa. Lablab's wild ancestor grows in hilly areas and coastal lowlands in southern, eastern, and western Africa. Its beans are small and apparently are not eaten. The cultivated form is known in Egypt, Sudan, and both East and West Africa.

Beyond Africa Lablab is most widely grown in South Asia and Southeast Asia (for instance, Malaysia, Indonesia, the Philippines, and Papua New Guinea). It is also known in the Caribbean, Central America, and the tropical zones of South America.

Horticultural Varieties

Although there are few formal varieties, lablab occurs in two botanical types. The garden type is twining and is grown on supports. It is late maturing and is employed mainly as a green vegetable. The field type is erect and bushy. It matures earlier but cannot be used as a green vegetable because even the green pods are fibrous and have an unpleasant smell. Over 200 genotypes are recognized. Despite the wealth of available germplasm, only a handful of registered commercial varieties are known in the countries that now cultivate the lablab.

Environmental Requirements

This is such an adaptable species that there are varieties for most kinds of conditions and locales. Speaking generally, however, the following are its

environmental requirements.

Daylength The plant is sensitive to daylength. Most genotypes require short days to initiate flowering, but long-day cultivars exist as well.

Rainfall Lablab is suitable for growing as a rain-fed crop where the average annual rainfall is 600-900 mm. In India it is successfully grown commercially, with supplementary irrigation, in areas with a rainfall as low as 400 mm. It requires adequate moisture during the early stages of growth, after which its deep roots enable it to exploit residual soil moisture. When grown as a market-garden crop for the production of the immature pods it requires watering or frequent rains throughout its growing period. Seed production can be a problem in regions with high humidity.

Altitude Locations up to and beyond 2,000 m have proved suitable for economic production, at least in equatorial nations such as Papua New Guinea.

Low Temperature For optimum results, a warm, equable climate is required, with average temperatures between 18 and 30°C. Many lablab types withstand frost for a limited period, although it is liable to cause leaf damage. Lablab is both self- and bee-pollinated, and cooler weather at flowering time can affect seed-set.

High Temperature Most—perhaps all—cultivars tolerate exceptional heat.

Soil The plant survives on a wide variety of soil types, provided they are well drained. It is reported to do particularly well on sandy loams that are slightly acid (pH 6.5), but in Brazil it thrives on heavy clays that are quite acid (pH 5.0). It cannot tolerate waterlogged or salty conditions. Little is known of any fertilizer requirements, but the plant reportedly responds to phosphate and potash. In experiments at Beltsville, Maryland, it grew well in soils ranging from acid to alkaline (pH 4.4 to 7.8) as well as in aluminous soils deadly toxic to most crops because of their level of soluble aluminum.[9]

[9] Information supplied by C.D. Foy.

11

LOCUST BEAN

The West African locust looks nothing like what Westerners might consider a vegetable plant to be. It is a tree. A true Jack-and-the-beanstalk kind of crop, it is indeed related to beans, albeit distantly. It often grows more than 20 meters tall, and people harvest all the pods they can get, sometimes climbing all the way to the top.

Outsiders might dismiss this as a tall tale, but they'd be wrong. Locust combines in a single species Africa's two greatest needs: food and tree cover. More locusts mean more food *and* more trees, which add up to more hope for a better continent.

Botanists named this plant genus *Parkia* in honor of Mungo Park, one of the first Europeans to record it. This intrepid Scottish surgeon-naturalist, who drown in distress attempting to unravel the course of the Niger River, would even now be hardly displeased with the honor. Two centuries on, his namesake plant still plays a vital role in the village and nomadic life of rural peoples living throughout the northern and western savanna regions.

Locust beans are attractive savanna trees, with dramatically spreading crowns and clusters of globular bright red flowers dangling like holiday decorations on long stalks. And they produce many benefits.

For one thing, they produce fruit. Numerous large pods, up to as long as your forearm and wider than your thumb, emerge all over the spreading crown, dangling like the fingers of a green or brown giant. Inside each pod is a yellow or orange dryish pulp. People like it, and no wonder: it can be half sugar and very sweet to the taste, almost like a desert. This mealy delight can make a useful baby food but for many children it may be the main—if not the only—dish, depending on what is left in the family's granary. It is also made into colorful and refreshing drinks. And it is dried down into a white or yellowish powder that can be stored for later use, at which time it is commonly sprinkled over rice or meat.

But sugary pulp is not this tree's main gift. Instead, it is the seeds enclosed within it that are the most prized product. These are a regular part of people's diet and, throughout much of West Africa, they also turn into lifesavers in times of famine. They contain about 30 percent protein, 20 percent fat, 12 percent sugar, 15 percent starch, and 12 percent fiber, as well

as vitamins and minerals such as calcium and iron. In sum, they are about as balanced and concentrated a food as could be devised. Add the fact that they mature in the dry season, the traditional "hungry time," and their value as emergency food becomes plain.

Reliability is key. Even when drought has seared the landscape, the products from this deep-rooted tree continue appearing on schedule. This is how they save lives. Indeed, they are so good at it that Muslim African tradition claims the tree to be a gift from Heaven—actually brought to Africa by the Prophet Himself. Their reliability as well as the fact that they remain available when most other vegetation has died certainly seems to indicate the hand of providence.

The most famous (or infamous) product from the seeds is a greasy extract with the stench of the strongest cheese. It typically comes in the form of sticky blackish balls, well known in West Africa, where itinerant traders barter them under the Hausa name dawadawa as well as under the name soumbala (Bambara- and Malinké speaking peoples of central West Africa). This fermented material keeps well even in tropical heat and is rich in protein, vitamins, and food energy. Mostly used as a seasoning, it is also an important soup ingredient.

Outsiders may scoff at dawadawa, but it is no less beloved by its aficionados than is limburger in Europe, fish paste in Indonesia and Vietnam, or Vegemite in Australia. Throughout the northern part of West Africa it is a regular dietary item. In some areas it is eaten at least once a day almost every day of the year.

Thanks to dawadawa, locust seed is a major item of commerce across West Africa. However, producing the pungent paste is a traditional family craft and, although some dried beans are sold in local markets, most are collected and processed by individuals for their own use. Overall, it is estimated that 200,000 tons of locust seeds are collected annually for dawadawa just in northern Nigeria.[1] Making and selling this product constitutes an important economic activity for women.

Because of all this, locusts—along with baobab (Chapter 3) and shea (Chapter 17)—are among the most commercially valuable of all parkland and farm trees in that and other parts of the region. Although they are among the commonest natural trees seen across the park savanna of West Africa, each one is the property of a nearby villager. Those ownership rights are worth hanging on to. As far back as 1964, the seeds from a single locust were valued at around $20 a year.

[1] Campbell-Platt, G. 1980. African locust bean (*Parkia* species) and its west African fermented food product, Dawadawa. *Ecology of Food and Nutrition* 9(2):123-132.

Saboba, northern Ghana. In this savanna region locust bean trees populate a field of the native cereal called fonio. The locust, which has received almost no horticultural recognition, combines likely answers to Africa's twin needs of food and tree cover. Its seeds are gathered by the thousands of tons and peddled by itinerant traders throughout West Africa. Chiefly, they are fermented into the famous dawadawa, a cheesy solid rich in protein, vitamins, and food energy. In some ways it takes the place of cheese or meat in a European diet. It keeps well without refrigeration even in the tropical heat and is popular as a seasoning and soup ingredient. (Yosei Oikawa)

Thus, locusts are sometimes the only trees to be seen in the West African savannas. They are left standing whenever bush is cleared. Indeed, several West African nations have laws against cutting one down. Some chiefs, stressing that the trees are living creatures in need of their protection, demand a fee before permitting the owner to harvest his own beans.

Despite all this monetary, nutritional, and environmental importance the species has seldom been accorded systematic silvicultural development, nor has it been promoted in regions outside its native habitat. Given the powerful possibility of increasing food production, rural development, nutritional well-being, and forest cover with one crop, this seems a shameful neglect.

Perhaps the idea of reforesting swatches of savanna with this food tree is extreme, but it is noteworthy that locust thrives on a wide range of alluvial,

sandy, and lateritic soils and has very low susceptibility to pests and diseases. It survives fires and thrives in full sun and tropical heat. Moreover, it is deep-rooted and almost independent of equable rainfall. According to some accounts, seeds sprout readily, seedlings transplant well, and young plants grow quickly. All this would seem to make locust an ideal candidate for planting in appropriate parts of Africa, especially the long-ago deforested savannas. They also make many shady, edible avenues for now sun-drenched cities, towns and highways.

PROSPECTS

Given its importance to traditional rural populations, this multipurpose legume could certainly be employed more widely and more intensively. The existing trees almost all grew up in the wild; how the species will respond to the hand of horticulture remains uncertain, despite the seeming evidence of the millions of existing specimens. It is encouraging that in recent years several projects have begun to focus specific attention on *Parkia biglobosa* to conserve its germplasm and extend the uses by improvement of agronomic measures.

Within Africa

Clearly prospects are greatest in West Africa, where the plant and its products are known and loved. A major constraint, however, is that the popularity of dawadawa may be diminishing. Possibly, this is because the product's quality is variable and its shelf life unreliable. Possibly, it is because European dried soups and bouillon cubes are highly promoted on the urban markets in francophone countries). Possibly it is due to the recent appearance of soybean substitutes, fostered through development agencies on the basis that soybeans are easier to grow and process. Quality dawadawa, however, still seems preferred everywhere, and should always have a ready market.

Humid Areas Unknown and unlikely. Possibly locust trees will survive under greater rainfall and humidity than they get in their native habitat; it seems not likely that they will become food crops there.

Dry Areas Here, locust trees are potential sources for food, edible oil, fodder, lumber, firewood, and green manure. Their particular importance is not so much for reforesting the deserts or the Sahel, but the savannas, parklands and agroforestry situations, where plant life is already present but not of great benefit. Trees that yield vital products in drought years could be good not only for people but for the whole area and the creatures in it. However, locust seems more sensitive to drought than many of its other companion species.

Upland Areas Locust seems likely to find a niche in warm upland areas, but that niche may prove too small for investment of targeted resources.

Beyond Africa

The plants are worth testing in tropical savannas worldwide. How they will perform is hard to gauge, but it seems possible that they will complement better-known nitrogen-fixing trees such as leucaena and calliandra by outperforming them in places just a little too dry for them to exert their normal vigor. It seems unlikely that locusts will be employed for food in such locations, but their other benefits to people and the soil are enough to warrant initial trials.

USES

Like so many species in this book, the locust provides a wealth of useful products.

Pulp As noted, the colorful pulp within the pod is eaten raw as a sweetmeat, mixed with water and made into a refreshing drink, used as a sweetener in different foods, and fermented into an alcoholic beverage. It is popular with children. It is also popular with travelers, and keeps so well that it is commonly taken on long journeys.

Seeds In the production of dawadawa the seeds are boiled up to 24 hours, pounded, cleaned, and rendered down into a black paste, which is then set aside to ferment. After two or three days the odoriferous result is pressed into cakes or balls. In the dry form these can keep for over a year in traditional earthenware pots, without refrigeration. Small amounts are crumbled into traditional soups and stews, which are usually eaten with sorghum or millet dumplings and porridges. (The dawadawa is added during the cooking process because the powerful smell then disappears.) Because of its savory taste and high protein and energy values, it is sometimes described as a meat or cheese substitute, but it is often more like a condiment that is eaten in tiny quantities. In parts of Togo, Ghana, Burkina Faso, and Nigeria daily per-capita consumption has been estimated at 4g, 2g, 12g, and 1 to 17g, respectively.[2] The seeds are also sometimes roasted as a coffee eaten in

[2] Ibid.

Dantokpa market, Cotonou, Benin. "Mustard" made from seeds of the savanna tree commonly called locust in English is essential for making nutritious soup. Across West Africa locust bean is a major item of commerce, as is its major processed form, dawadawa, a nutrient-dense, cheese-like food. These together constitute an important economic activity for women. Production of the pungent paste is a traditional family craft and although most is produced for home use, some ends up being sold in local markets. (L.J.G. van der Maesen)

tiny quantities. In parts of Togo, Ghana, Burkina Faso, and Nigeria daily per-capita consumption has been estimated at 4g, 2g, 12g, and 1 to 17g, respectively.[3] The seeds are also sometimes roasted as a coffee substitute, "café de soudan."

Wood The white, yellow, or dull brown wood is soft, medium-grained, and easily worked. It is said to be of less than top quality, but is used for house posts, mortars, bowls, and some carpentry. Most, however, goes for fuel. In the 1970s, it was estimated that locust probably constituted over 90 percent of the firewood supplied to Kano, a Nigerian city whose population was over 250,000 at the time.

Shade The tree makes a superb avenue tree, especially for the drier regions, where shade is perhaps the most precious of all commodities. In thousands of villages it is planted at eating- and meeting places, for shade, for shelter from desert winds, for beautification, and as an insurance against the several times in a generation when it is needed to save lives.

[3] Ibid.

Land-Improvement Not only is this a useful windbreak and shade tree, it is a benefit to the soil. Sites beneath this legume are improved by dung and urine of the livestock sheltering there (attracted by the shade and possibilities of browse). They are also improved by the leaf fall, which is so abundant and so rich in nitrogen and minerals that in certain places the leaves are collected for soil improvement, like manure.

Living Tree Locust is one of the trees that provide poor people a toothbrush. Its twigs are used to brush thousands of teeth a day in countries such as Niger. The bark stains the mouth red but the soapy compounds (saponins) it contains clean teeth. Locust also provides good bee forage. And the fruits and seeds are consumed by a wide variety of animals, including monkeys, making the trees friends of wildlife as well as people and the land.

Forage The sugary pods are much relished by cattle and other domestic livestock. Throughout the region they provide a valuable dry-season ration. The leaves also are traditionally used, whole branches being lopped for fodder. During the dry season, when other feed supplements are scarce or impossible to find, both the ground-up seeds and the sugary pulp are relied on as pig food in northern Nigeria.

Medicinal Uses The bark is an ingredient of ancient remedies sold in Senegalese and other West-African markets or used in the villages. It is also sold for mouthwash, vapor inhalant for toothache,[4] or ear complaints. Many trees in the sub-Sahel zone appear maltreated from harvesting square patches of bark about 15-20 cm square.

Plaster The pod valves can be fermented in water and the resulting liquid is used to decorate walls of loam houses (e.g., in Burkina Faso).

NUTRITION

Although not eaten in quantity, the seeds make a concentrated food containing a nice balance of protein, fat, sugar, starch, and fiber, not to mention vitamins and minerals. About 7 percent of the protein is lysine, a level similar to that in whole egg, one of the best protein foods known. Unfortunately locust seeds are deficient in two other critical amino acids, methionine and tryptophan.

The fat in the beans is nutritionally important. Approximately 60 percent is unsaturated, the major fatty acid being linoleic, a nutritionally useful

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[4] Perhaps it contains acetyl salicylates, a feature that gave rise to aspirin when they were found in willow bark in Europe in the 1800s.

ingredient often missing in poor-people's diets.[5]

The fermented locust-seed product, dawadawa, is equally nutritious. It too is rich in protein. Like the bean itself, it is deficient in certain amino acids, but is rich in lysine. In addition, it contains about 17 percent of a semisolid fat. Further, it contains an array of vitamins, notably vitamin B2.

The floury pulp surrounding the seeds in the pod, sometimes called dozim, is an energy-packed food with up to 60 percent sugar. It is also high in vitamin C (291 mg per 100g dry matter in one analysis[6]). This is yet another locust food that becomes available in the season when little else is available for the picking.

HORTICULTURE

Although there are no known major plantings, methods for producing the plants in nurseries have been elaborated.[7] The trees can be propagated by seed, which grow rather vigorously. An overnight soak in hot water has been suggested as a pretreatment.

Vegetative propagation is also possible, but apparently is difficult. Trial plots of grafted locust have been established by CNSF in Burkina Faso. The tree also has been propagated by budding, to produce early fruiting, in Nigeria.[8] Pruning of seeding trees is said to hasten fruiting.

HARVESTING AND HANDLING

Pods are picked from the tree, sometimes by climbing but more often by using a long pole fitted with a knife at the end. Transporting these flat leathery pods presents few problems. Most are hauled around roughly in baskets or sacks.

LIMITATIONS

Just how good a return any planter will get is mere guesswork. The seed yield is reported to be low (between 350 and 500 kg per hectare), a feature to be expected in a wild plant and one that would likely improve dramatically in managed plantations.

The seeds have tough leathery seedcoats; they have to be cooked or peeled before eating. Even more than for some other pulses, cooking times for the toughest beans can extend out twelve hours or more, consuming large amounts of precious fuel.

Though no part of the fruit contains cyanogenic glycosides, the raw seeds

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5 Odunfa, S.A. and A Adesomoju. 1986. Fatty acid composition of African locust bean (*Parkia biglobosa*). *Chemie Mikrobiologie Technologie Lebensmittel* 10:125-127.
6 Campbell -Platt, op. cit.
7 For example, by the Forest Seed Centre of Burkina Faso.
8 Information from J.C. Okafor.

are suspected of containing anti-nutritional factors. Those must be eliminated in the cooking process. It is reported, for example, that in cooked locust seeds the only factors that lower nutritive value are the low levels of methionine and tryptophan. This was deduced from the fact that diets supplemented with those amino acids increased the growth of rats to almost that obtained with whole egg.

Although the mature tree is a fire-resistant heliophyte that needs little protection or care, the seedlings are harmed by browsing and hence need careful safekeeping from wandering livestock.

General distribution of locust bean. It is noteworthy that the tree thrives on a wide range of alluvial, sandy, and lateritic soils. It also resists pests and diseases, resists fires, and thrives in full sun and tropical heat. Moreover, its deep-roots make it almost independent of equable rainfall. All this would seem to make locust an ideal candidate for mass planting in appropriate parts of Africa, notably the once-forested savannas. (M.R. Daffron, after Frost Entomological Museum, Pennsylvania State University and other sources)

NEXT STEPS

To turn locust into a reliable food resource, there are many steps that could be taken and a few that must be taken. Both are mentioned here.

Plantings Ideally, a major initiative could be mass planting of locusts wherever they can take root and thrive. Also, fostering village plantings can be recommended. At that time a key barrier will be the availability of sufficient top-quality seed. Given high expectations, it would not be amiss to establish seed plantations in preparation for the day of mass demand. As an agroforestry species, it can be highly recommended—no delay for further research or trials seems necessary. Perhaps its greatest promise will occur on lateritic sites. The growth is stunted but under such circumstances growth rate is far less important than survival. These red, acid, aluminous, mostly barren soils beset the tropics, and are one of their main causes for low productivity and hunger.

Locust would appear to be a superb multipurpose agroforestry species. Many areas have lost much of their tree cover, and farmers have begun to reestablish specific beneficial species, including locust. The promotion of maintenance, strengthening and reestablishment of such agroforestry associations would seem to hold the best prospects for the tree in local livelihood systems. Possibly, locust could be planted in association with

Labé, Guinea. Farmer shelling locust beans. Although a regular part of the diet, the beans become lifesavers during times of famine. The seeds contain protein, fat, sugar, starch, fiber, vitamins, and minerals, and are a concentrated and very balanced food. Add the fact that they mature in the dry season, the traditional "hungry time," and their value as emergency rations becomes plain. Even when drought has seared the landscape, this deep-rooted tree continues producing food almost as if independent of the weather. (IFAD/Roberto Faidutti)

shea and the occasional baobab.

Small cooperatively managed plantations, especially those owned and managed by women, might be a real boost in some places. On the other hand, investment in larger-scale plantations by business people and civil servants from the city might destroy entirely the cottage industry based around the production and sale of dawadawa, which comprises a significant portion of women's, albeit meager, incomes across the region.

Horticultural Improvement Because there have been few conscious attempts at yield improvement there is probably much potential to select for improved yields. Many approaches seem promising. For one, research into pests and diseases, plant nutrition, and cultivation techniques may lead to vast improvements. For another, plant physiological research may indicate ways to encourage a larger number of hermaphrodite flowers to develop into pods. Some evidence suggests that trees in plantations perform better than isolated trees, and improvement of plantation establishment techniques could contribute substantially to production.

Genetic Selection A selection of superior strains is certainly needed.

Throughout West Africa there are many varieties with different forms, seed sizes, seed colors, and so forth. Ample germplasm exists for selection and breeding work. Thus, there is much scope for selection and building up extremely productive plantations by choosing superior specimens. Establishment of provenances, documentation of genetic variation, selection for improved cultivars, (e.g., precocity in fruiting) is also needed. In sum, this species is like a recently opened book, just waiting to be read by more locust lovers, students, plant scientists, and nurserymen.

Vegetative Propagation As stated, both grafting and budding have been conducted successfully. “Plus trees” could be selected as the basis for seed orchard establishment, with tree planting campaigns promoting locust bean trees using budded seedlings.

Management Pruning trials should also be carried out with the existing seedling trees, with active participation of local farmers. It is said that pruning speeds fruiting.

Pollinators Wind, bees, and flies all contribute to pollination, but it is also reported that bats can be major pollinators of locust trees. Encouraging bat populations in plantations could be very helpful for increasing seed.

Food Technology There is a need for research into the presence of alkaloids in the seeds. These are possibly confined to the seedcoat (testa), which is usually removed before the seed is used as food.

Additionally, the whole process of commercial dawadawa production needs modernization research.[9] Such things as defined starter cultures and standardized (and sterile) processing might provide more consistent flavor, improve shelf life, and help maintain its overall popularity. Also, processing methods that reduce the smell might be developed, so dawadawa can better compete with soybean substitutes and bouillon cubes in the commercial markets. Moreover, technologies that require less labor and fuelwood would truly help the producers.

Sustainable Agriculture

There is the possibility of creating continuous cropping systems around locust. Deep-rooted trees such as this could be a key in semi-arid areas. The short rainy season is the limiting factor to farming, if not life, and therefore the cropping systems in these areas have to be designed on the basis of the water availability.

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[9] Achi, O.K. 2005. Traditional fermented protein condiments in Nigeria. *African Journal of Biotechnology* 4(13):1612-1621; online at academicjournals.org/AJB.

SPECIES INFORMATION

Botanical Name *Parkia biglobosa* (Jacq.) R.Br. ex G.Don

Major Synonyms *Parkia africana* R.Br., *Parkia intermedia* Oliver, *Parkia clappertoniana* Keay.

Family Leguminosae. Subfamily: Mimosoideae.

Common Names

Bambara: néré
English: African locust bean,
French: arbre a farine, arbre a fauve
Nigeria: nitta, nete, nere, dawa-dawa, dawadawa, dadawa, ogiri okpi (Igbo)
Fulani: narghi
Gambia: monkey cutlass, netetou
Sierra Leone: kinds
Sudan: dours
Chad Arabic: maito
Kanouri: runo
Djerma: dosso
More: rouaga

Description

African locust trees are large in size: typically over 18 m high and 1.5 m in trunk diameter. They are considered handsome, with clear, rough-textured trunks, fine feathery bipinnate leaves made up of many leaflets, and red, club-shaped flower heads about 5 cm in diameter. The pods are 15-42 cm long and 2 cm wide, and appear in long hanging clusters. The trees lose their leaves during the dry season. Indeed, they are often wholly or partially leafless whilst flowering.

The flowers begin to open at dusk, close and wilt at dawn, lasting only a single night. They are reportedly hermaphrodite. However, the topmost flowers in each cluster are said to be sterile, and produce copious amounts of nectar, presumably to attract fruit bats. While open, the flower clusters resemble pom-poms, an ideal structure for bat pollination. Bees also frequent the flowers in the early hours of the day, and are certainly important pollinators.

Distribution

Locust is not strictly a Sahelian species. It is more properly a savanna species, common also in deciduous forests. In Senegal it extends to the northern limit of the Sudanian Region; further east it is less widely distributed in the drier northern parts, but reaches the southern boundary of the Sahel in Nigeria and Niger.

Within Africa Senegal, Gambia, Mali, Guinea-Bissau, Guinea, Sierra Leone, Côte d'Ivoire, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, Cameroon, Chad, Central African Republic, Sao Tome, Gabon, Democratic Republic of Congo, Sudan, Uganda.

Beyond Africa African locust is found on several Caribbean Islands. It is naturalized in Haiti, for instance. Possibly, this is a holdover from the slave trade, and the African love of locust.

Horticultural Varieties

No formal varieties exist. There are considerable genotypic differences, often well known to locals, that are proving useful in making formal selections.

Environmental Requirements

Rainfall The species has been observed growing where mean annual rainfall is 400 mm, but it usually occurs where rainfall is 600-700 mm. It has also been recorded where rainfall is 1200 mm.

Altitude The limits are unknown, but altitude is probably not a practical limitation, at least in equatorial latitudes.

Low Temperature Freezing weather is foreign to its native habitat, but the plant is certainly frost sensitive.

High Temperature Locust trees thrive in semiarid tropical climates with an average daily maximum above 33.5 °C.

Soil It is adapted to a wide range of alluvial soils and is known to grow on shallow drift sands as well as on deep, heavy sand (the type on which sorghum grows well). It does best, however, on deep, cultivated soils but occurs on shallow skeletal soils and is known to survive on poor, rocky sites. In technical terms, it has been said that the sites suiting locust are those with tropical ferruginous soils, ferrisols, and moderately leached ferralitics.

Related Species

Parkia filicoidea. is a related African species from riparian forests. Other species occur both in tropical Asia and Latin America. These are generally handsome, quick-growing trees, large in size, with clear, smooth trunks and fine feathery leaves. They too are useful and highly regarded. Most are pollinated by bats as well as bees. Examples include:

- *Parkia speciosa*. Indigenous to Southeast Asia, where it can be found in cultivated plantations. There the odorous/stinking seeds are eaten raw. roasted and fried after sun drying and storage, or else cooked in sauces and curries, more as a condiment. In Indonesia and Malaysia, the pods are an important foodstuff. When ground into a meal, they make a nutritious ingredient of livestock rations. These trees may be found in fairly moist areas in southern Asia. Many of the species are noted for the pods or beans and nuts they bear, which are of good quality and make excellent and nutritious foodstuffs. The leaves also provide useful forage for livestock.
- *Parkia biglandulosa*. Malaysia. Seeds roasted, also a substitute for coffee; seedlings also consumed.
- *Parkia intermedia*. Indonesia. Seeds eaten raw or roasted.
- *Parkia javanica*. Indonesia, Philippines. Pods used for flavoring.
- *Parkia roxburghii*. Thrives in moist low areas up to about 600 meters above sea level.

These further members of the genus *Parkia* are worthy of much more extensive planting, with progressive breeding and selections of improved strains. Several institutions in various parts of Asia and the Americas have begun showing an interest in developing them for forestry and farms.

12

LONG BEAN

In Asia there is a special vegetable, renown by growers for its productivity, by chefs for its appearance, and by diners for its flavor and tender-crisp texture. Reportedly, it is one of Southeast Asia's top ten vegetables, grown especially in southern China and Taiwan. That report, however, does it less than justice. In addition, it is the most widely grown legume of the Philippines, where it is known as "poor-man's meat." It also is very well known in Indonesia, Thailand, Vietnam, Bangladesh, India, and more.

In recent decades, this popular bean has begun picking up aficionados far beyond Asia. Indeed, there is now a rising regard for it worldwide. Many countries already consider it a leading Oriental vegetable. In Europe, for instance, it is being grown extensively. And the United States has also begun producing it on a large scale for Chinese, Thai, Filipino, Vietnamese, and Indian restaurants. It is now found year-round in America's Asian markets and in those supermarkets that have specialty produce sections. Yet the demand keeps rising. California growers, for example, can't seem to produce enough; importers bring in additional supplies from Mexico and the Caribbean to meet the needs of places such as Los Angeles and San Francisco.

This special foodstuff is the pod of an unusual legume. It resembles a snap bean except for one singular fact: it is pencil-thin and as much as a meter long. Often called yardlong bean in English, these green to pale-green pods are tender, stringless, succulent, and sweet. Typically, they are sliced and boiled and served with a little butter, like string beans. Their crisp texture and flavor hold up well when steamed or stir-fried. Most enthusiasts claim they resemble French beans. Some detect a mushroom-like taste. A few note in them a hint of asparagus, a connection reflected in this plant's other common name, "asparagus bean." All agree, however, that it is delicious.

A surprising thing about this "Oriental" vegetable is that it is not from the East at all. In the beginning—thousands of years ago—it was unknown to any Asian, or for that matter any European or New World inhabitant. But it was well known to Africans. This historical fact is a fairly new realization. A century ago even botanists were fooled into labeling the plant *Vigna sinensis* (bean of China). But now we know that it is nothing more than a

This delightful vegetable resembles a snap bean except for the singular fact that it is pencil-thin and up to a meter long. Often called yardlong bean in English, its green to pale-green pods are tender, stringless, succulent, and sweet. A surprising thing about this universally acclaimed "Oriental vegetable" is that it is a very special form of cowpea—a plant of unquestioned African origin (see Chapter 5). Now is the time to welcome long bean back home and put it to work in Africa. (East West Seeds International)

very special form of cowpea, *Vigna unguiculata*—a plant that unquestionably arose out of tropical Africa thousands of years ago (see Chapter 5).

This ancient African, which has blossomed to become a modern Queen of Asian Cuisine, is an oddly shaped vegetable, so long as to seem grossly out of proportion. No wonder some people call it snake bean. The strange thing is that this snap-cowpea's main evolution happened after it left home, so the long, long, long pod is hardly known in the lands that gave the species birth.

Now is the time to welcome back this child of Africa, and to put it to work as in the rest of the world. Indeed, in principle at least, this wanderer from the local genepool should be in virtually every African village. It lends itself to poor people's needs and conditions. It is productive, yielding a lot of food in a very small space. On worn-out soils it is said to outyield peanuts. A true legume, it is largely independent of fertilizer….enriching soil by trapping atmospheric nitrogen in nodules on its roots. It is not only tasty; it fits into African cuisine, especially the vegetable-laden sauces and relishes.

Long beans thrive in hot humid climates, and produce food very quickly.

Indeed, the succulent leaves can be harvested as soon as 21 days after planting, and some types produce harvestable pods within 60 days. The main varieties continue producing over long periods of time, thus giving rise to an extended harvest that keeps providing fresh pods for months.

That harvest is salable, profitable and, above all, nutritious. Not for nothing do Filipinos call it poor-man's meat. Both seeds and tender leaves contain 25 percent protein, of high nutritional quality. The US National Aeronautics and Space Administration is so impressed with this plant's nutritional potential it is considering growing it in space to feed astronauts.

PROSPECTS

There are bright prospects for long bean in the African diet.

Within Africa

Already in certain parts of Africa cowpea pods are eaten. For this reason, the extra-long, highly developed versions now livening cuisines and brightening dinner plates from New Delhi to New Orleans won't arrive as a foreign food. They are meatier, sweeter, and a paler shade of green than are Africa's current type. Thus, these foreign counterparts should take on quickly when people find how tasty and tender and attractive they are.

Humid Areas Excellent.

Dry Areas Good. Cowpeas are especially important in regions that are a little too hot and a little too dry for beans and peanuts. Although for top production and pod quality they need water, this is not so difficult to provide in an intensively produced backyard crop. Long bean, however, may be less drought tolerant than cowpea even though it is the same species.

Upland Areas Good. Long beans are said to produce poorly at elevation in the tropics. Nonetheless, there are many pockets where temperatures will prove conducive to this fast-maturing annual.

Beyond Africa

Although the long bean is far better known outside its African homelands, it still has untapped potential in Asia, Europe, and the Americas. Yet that potential is likely to be exploited without too much help from public science.

USES

This is another multipurpose plant.

Pods The pods are picked when they are still smooth and immature, before the seeds swell. They are eaten fresh, frozen, or canned. At this young and tender stage, they can be prepared in various ways. Most are sliced and sautéed or stir-fried. Recent suggestions by a cookery consultant include the following: stewed with tomato sauce; boiled and drained, then seasoned with lemon juice and oil; or simmered in butter or oil and garlic. Overcooking is to be avoided: it turns them mushy.

Shoots In many parts of the tropics the young stem tips are steamed or boiled and eaten like asparagus.

Leaves In many areas the leaves of long bean (as well as of cowpea) are also regularly consumed. To make a good spinach the leaves must be young and tender.[1] Although they are usually simply boiled and eaten, some are crushed, fried, and boiled. Also, some cowpea leaves are dried and ground into a powder that is stored for use during the time of year when fresh vegetables are scarce. In some areas, the mature leaves are boiled about 15 minutes, drained, dried in the sun, and stored for use as a relish. The rapid boiling (blanching) improves the storage and quality.
Experiments in Uganda and Tanzania have shown that removing all the tender leaves three times at weekly intervals, starting five or seven weeks after sowing, has no adverse effect on cowpea seed yields (although it may delay flowering). Thus, even the growers of the grain type can benefit from these cowpea greens.

Other Uses Long beans can also be used as fodder. In India and some other countries, cowpea is grown as a dual purpose crop: the green pods are harvested for use as a vegetable and the residual plant material, containing about 12 percent protein on a dry matter basis, is used for feeding livestock.

NUTRITION

Long bean pods provide only about 50 calories per 100 g when cooked, and are low in protein (>3 percent[2]). They also provide modest vitamin C (about 15 mg) and provitamin A (23 µg RAE), but have good levels of folate (about 45 µg), so critical for growing new cells during pregnancy and infancy. As noted, the tender leaves of the plant are nutritious as well. These contain 25 percent protein as a percentage of dry weight, and the protein is of high quality.

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[1] One commentator claims that the best leaves are "the third and fourth from the apical ends of the shoots."
[2] Mature seed, sometimes eaten in Asia instead of the immature pods, contain about 25 percent protein when dry.

This productive legume yields a lot of food in a very small space. On worn-out soils it is said to out-produce peanuts. A true legume, it is largely independent of fertilizer—enriching soil by trapping atmospheric nitrogen in nodules on its roots. It not only fits into African farming it fits into African cuisine, especially into the vegetable-laden sauces and relishes. These tasty, universally admired treats therefore hold out the prospect of a good income for those who choose to grow them for profit. (East West Seeds International)

HORTICULTURE

Long bean is a vigorous annual that is propagated by seed. Its long, trailing growth requires a trellis or pole for best production. The plant will climb by itself, but still needs some help and a very strong trellis system. Poles are also satisfactory, especially if slanted. Training the vine is said to be no more difficult than training a tomato or pea plant.

Typically, the seeds are planted in rows beside a trellis or in hills beside a pole. In the latter case, it has been recommended that 5-6 seeds be planted together for each pole, and then thinned to leave 3 seedlings.

The plant begins producing marketable pods 60 days after sowing. At that stage the pods, hanging in pairs, range from 35 to 60 cm in length. Each pod forms rapidly, growing to marketable length in just 9 days after the flower opens.

The plant thrives in average garden soil that is loose and friable. Soil that is too rich in nitrogen fosters leaf growth over pod production. Since these are legumes, some growers inoculate the seed with nitrogen-fixing bacteria as an alternative to using nitrogen fertilizer. Long bean uses the cowpea (EL strain) rhizobium, which means that it will grow well wherever cowpea does. Thus, in most of Africa no inoculation should be needed. Elsewhere, and especially on barren soils, commercial cowpea inoculum is readily available.

The fact that this versatile crop is a form of cowpea (blackeye pea to Americans) is clear if the plant is let go to seed. In parts of China, long bean is allowed to mature a crop of seeds at the end of the season.

HARVESTING AND HANDLING

The pods keep coming throughout summer and into the fall, and have to be harvested frequently (weekly, if not daily). If they are left unharvested the plants stop producing. They are usually picked when about half the diameter of a pencil, before the seeds have filled out inside, and when they still snap when bent. If that stage is missed, the seeds swell and the pod itself turns tough and inedible.

Yields depend on the site and the grower, but in a field test at Riverside, California researchers measured marketable yields of up to 11,100 kg per hectare with three different cultivars of bush long beans.[3]

The pods are best when eaten soon after harvesting but they can also be blanched and frozen for storage. If refrigerated, they keep in a plastic bag for up to 5 days. US Department of Agriculture recommendations for commercial dealers are to store them at 4°-7°C and 90-95 percent relative humidity, which provides a storage life of 7 to 10 days.

[3] Apparently, the testers quit counting while the plant was still bearing more pods. “Based upon the plants and their fruiting condition at the end of the harvest as well as the indeterminate nature of the crop,” they said, “the potential yield was probably greater.”

Marketing long beans is usually not too difficult. However, they must be picked exactly on time and handled with care. As one review noted: "It is easy to make them look bad…old, dry beans look terrible." The reviewer recommended choosing "slender, crisp, blemish-free beans" and warned that harvested pods quickly develop "rusty patches."

LIMITATIONS

As with common beans, it is recommended to rotate the planting locations every year and not plant at the same spot within 3-4 years.

In different locations different pests are likely to be encountered. Root-knot nematodes (*Meloidogyne* sp.) cause severe problems on cowpea in many areas of the world, including the US. Nematode resistance varieties are the best and most economical solution to this problem. In California the following warning has been given: "Aphids, particularly the cowpea aphid (*Aphis craccivora*), are drawn to the pods, leaves and stems. Planting the crop near others infested with this aphid, is 'asking for trouble.' Thrips tend to be a pest early in the season if temperatures are cool, but the plants will often outgrow them, especially as the weather gets warmer and the plants grow faster. Mites can be a problem, primarily after insecticide applications, which often lead to mite outbreaks." Lygus bug (*Lygus Hesperus*) attacks the young floral buds and developing pods of blackeye cowpeas so if potentially a severe problem on long bean as well. In the southeastern United States, cowpea curculio and pod sucking bugs (including the green stink bug *Nezara viridula*) are major pests of cowpea and will attack long bean as well.

It seems logical to assume that long beans are susceptible to all cowpea diseases. Indeed, the same report from Califonia noted that, "they are damaged by fungi causing rust and mildew as well as by cowpea aphid-borne mosaic virus and cowpea witches' broom virus. Virus control is aided by destroying infected plant materials and controlling aphids, whiteflies, leafhoppers and beetles that carry the virus from plant to plant. [Long beans] often are relatively pest-free compared to green bean varieties; however, the bean shoot fly and the bean pod fly may hamper growth and pod production. Remove and burn damaged plant materials to prevent spread of pest species."

NEXT STEPS

Because of global experience with long bean, African nations could mount programs right now to foster its adoption and better use. Anyone involved in vegetable production in Africa could get involved. A continent-wide program to advance and nurture long bean could take advantage of the varying experiences among countries. The best seeds and knowledge exist in Asia, so there could also be an intercontinental swap of germplasm and

expertise. Many varieties unknown in Africa are available, generally identified by the color of mature seed. Examples include the purple-hulled, pink-eyed, dark-brown seeded, white-seeded, and speckle-seeded. There are also purple-podded and knuckle-podded varieties. Asian countries could do much by transferring seeds and horticultural know-how, and could possibly receive much in return from the biodiversity of long bean's ancestral home.

As noted, cowpea pods have been traditionally eaten in some areas of Africa. Even now, these, together with the plant's fresh green leaves, are exceptionally important because they are among the earliest foods available at the end of the "hungry time." Together with long bean, these are equally deserving of support and improved use.

Africans are not used to eating green cowpea pods as a green vegetable, but rather they prefer dry cowpea grain. They need to know that long bean is better consumed as green tender pod, for seed of long bean is lighter than cowpea, and so are not as productive when seed is used compared to green pods.

Food Technology This "new," elongated cowpea pod should be checked in various African dishes. This would likely turn up many a potential market success. Frozen vegetable processors should try long bean in mixed packages of frozen vegetables.

Horticultural Development The newer bush varieties in Asia also deserve consideration. They have the same meter-long pods but require no trellis or pole and thus are easier to manage. In the Philippines, Bush Sitao (a cross between long bean and common cowpea) reportedly is replacing the viney form in the favor of farmers. It is bush-shaped, needs no trellis, and is less susceptible to wind damage than long bean.

The International Institute of Tropical Agriculture in Nigeria has developed several lines of vegetable cowpea that resemble long bean in some respect (tender pods). The lines were actually developed from the Philippine "bush sitao." Most are determinate plant type.

There is a concern of heavy pesticide use in long bean in Southeast Asian countries. This is an area where research is needed to find ways to produce this crop using reduced or minimum pesticides.

SPECIES INFORMATION

Botanical Name *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.

Synonyms *Vigna sinensis* subsp. *sesquipedalis* (L.) Van Eselt.; *Vigna sesquipedalis* (L.) Fruwirth

Family Leguminosae. Subfamily: Papilionoideae (Faboideae)—Pea family

Common Names

English: yardlong bean, asparagus bean, bodi bean, snake bean, Chinese long bean
French: dolique asperge, dolique géante, haricot kilomètre, haricot asperge
Portuguese : feijão-chicote, feijão-espargo, dólico gigante.
China: dow gauk, dou jiao, chang qing dou jiao, chèuhng chèng dauh gok (Cantonese), ch'eung ts'ing tau kok (Cantonese)
Philippines: sitaw, sitao (Tagalog), hamtak, banor (Visayan), balatong (Ilongo)
Indonesia: kacang belut, kacang tolo
Malaysia: kacang panjang, kachang panjang
Thailand: Tua fak yaow, Tua phnom.
Hmong: taao-hla-chao
Japan: juro-kusasagemae, sasage, juuroku sasage
Vietnam: dau-dau, dâu dûa, dâu giai áo

Description

This is a pole-type bean, growing 3 to 4 m high. The flowers, which are conspicuous and apparently self-pollinated, are borne on short pedicels and may be white, pale-blue, pink, or violet. They commonly open early in the day and close around midday, only to wilt and collapse. The pods can vary greatly in size, shape, color, and texture. They may be linear, curved, or coiled, and normally vary from 8 to 45 cm in length, but can reach 100 cm. They are indehiscent, usually pale green or yellow when ripe, although brown or purple-colored ones can occur. They normally contain 8-20 seeds, which also vary in size, shape, and color. The commonest, however, are white, creamy-white, or black.

These thin, soft beans may grow on delicate stems but they are supported by a tenacious root system. The plant is indeterminate, meaning it continues to grow after flowering and fruiting.

Distribution

Within Africa On the basis of modern evidence, there is no doubt that the cultivated cowpea originated in central Africa from where it spread in early times through Egypt or Arabia to Asia and the Mediterranean. Fifty years ago the British botanist, Burkill, stated that the cowpea reached Sumeria about 2300 B.C. Perhaps that was the first leg of its journey away from Africa. In its new home across the seas, this wandering scion of cowpea took on the new guise of a long, long bean and began masquerading as an Asian food.

Beyond Africa Long bean has been introduced to many lowland tropical countries where often it is a garden vegetable. The plant was taken to the West Indies in the 1500s and reached today's United States in about 1700. It is popular in the Caribbean and is grown as a summer crop in California, and has become increasingly popular with home-gardeners in the United States. In parts of Europe it is grown especially as a greenhouse vegetable. The crop is produced most widely in the Far East. China and India are both modern centers of long-bean diversity, but unique varieties are to be found in most Southeast Asian nations.

Horticultural Varieties

Dozens, scores, probably hundreds of different types are featured in catalogs of seed companies in worldwide. These are worth trying, although many will differ only in color and other cosmetic features. Varieties from the tropics may be photoperiod sensitive and will not flower under the longer days of summertime in temperate or even subtropical regions.

Environmental Requirements

This warm-season crop can be planted in a wide range of climatic conditions, but is sensitive to temperature and grows relatively slow in mild or cold environments.

Rainfall Long beans easily tolerate drought but the pods shrink and turn fibrous when starved of moisture. All in all, the long-podded varieties require more water than cowpeas grown for seed. Annual rainfall up to 1,500 mm has been recommended.

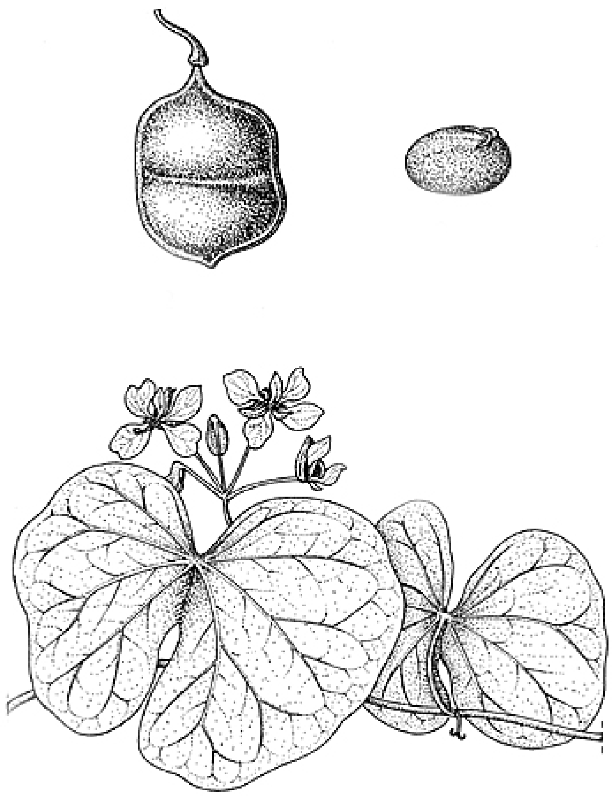
Altitude Despite claims to the contrary, elevation seems unlikely to limit this crop.

Low Temperature Long beans virtually cease growing when daily maximum temperatures are below 20°C. They must be sown after all danger of frost has passed, and to germinate well the soil should be 20-22°C,

otherwise the seeds tend to rot.

High Temperature Long beans prefer high temperature, conditions under which other green beans cannot be produced. Environments with full sunlight attaining daytime temperatures of 25-35° C with nighttime temperatures that stay above 15° C are preferred.

Soil This plant thrives in average garden soil. The plant is a true legume with nitrogen-fixing symbiosis; soil with already too much nitrogen favors leaf growth over pods.



Drawing courtesy of PROTA (prota.org); redrawn and adapted by Achmad Satiri Nurhaman

13

MARAMA

Strange that marama has not been introduced into cultivation. Above ground, this plant produces seeds that rival peanut and soybean in composition and nutritive value. Below, it produces a high-protein tuber much bigger and more nutritious than any potato, yam, or even sugar beet. And the plant also yields top-quality vegetable oil. In addition, it thrives in poor-quality soil and under the harshest of climates. Indeed, in its native habitat droughts often last years on end, a feature ruinous to mainstream crops and most living creatures but not to marama.

Moreover, the life-giving propensities of this resilient species are by no means restricted to food. The plant probably survives the seemingly interminable droughts by drawing on water stored in its tuber, which in dry years shrinks dramatically. Some of those tubers hold an immense amount of water. One dug up in Botswana weighed 277 kg, perhaps 250 kg of which would have been water. In arid and semiarid regions these “living cisterns” become important emergency sources of water for both humans and animals.

Despite these surprising qualities, though, little is known about the plant and almost nothing is understood about its cultivation. Among Africa’s many native foods, this remains one of the most neglected. Yet, the record clearly shows that a dedicated research and development effort might well lift this wild species out of obscurity and perhaps project it far enough to contribute importantly to the food supply in some of the most challenging of all agricultural locations.

Marama is endemic to southern Africa. Native to the Kalahari and neighboring sandy lands, it has a long history as a resource. Indeed, humankind is believed to have originated in this general area; marama may have been in our diet as long as any food in existence. Even today it is an important dietary component for some in the region. People in remote settlements and among nomadic groups rely on it as did our earliest ancestors. It is, for instance, a popular delicacy of the Herero, Tswana, and other Bantu-speaking peoples and is a key part of the diet of some Khoisan peoples (!Kung and Khoi-khoi). For some !Kung only mongongo nut surpasses it in importance as a life-sustaining foodstuff.

For all that, the plant has never been regularly cultivated. This is what is so strange. Marama is a rich source of protein and energy, and nourishes

Marama is a wild plant of the southern African deserts. A source of concentrated protein and energy, it nourishes people in regions where rainfall is so slight and erratic that in some years almost no moisture falls whatever. The plant withstands blistering temperatures with ease. It thrives in poor-quality soil. But it remains undomesticated and before anyone can truly capitalize on its amazing qualities a wealth of horticultural development is needed. (Lorna K. Marshall)

people in desert regions where rainfall is so slight and erratic that in some years there is almost no precipitation whatever. The plant withstands blistering summer temperatures apparently with ease. In addition, it survives low winter temperatures, especially the freezing nights of the Kalahari. And yet it is not being raised under the kind of controlled conditions that could bring out its best.

This neglect is not due to scarcity. Within the Kalahari region this is not a rare plant. In some areas of Botswana and Namibia, marama occurs in stands several kilometers across. It is found to a lesser extent in South Africa (northern Cape Province and Gauteng). The typical habitat is an undulating grassveld (savanna), with marama sprouting among the native grass and acacia-thorn scrub on sandy vlies.

It is not due to an unpleasant taste. After roasting the seeds take on a nutty flavor that has been compared with roasted cashew nuts. Europeans in southern Africa have ground the roasted seeds and used them as a culinary substitute for almonds. Africans often boil them with cornmeal or grind or pound them into a powder that is boiled in water to produce either a cocoa-like beverage or a porridge. In taste, then, marama ranks with the best.

Nor is it due to the impossibility of producing the plant in an organized manner. Although no concerted effort at domestication has been undertaken,

it was reported in the early 1960s that, for 20 years, farmers near Barberspan (Western Gauteng) had encouraged the plant by sowing its seeds in spring (October) directly into sand without any preliminary plowing. Following the mention of marama in an earlier book from this office,[1] trials were reported in several parts of the United States in projects located in Texas, Florida, and California, and the plant grew satisfactorily.

PROSPECTS

Despite the fact marama is still a wild plant with vast uncertainties to answer before it can cultivated on any scale, marama seems to have notable prospects solely on the basis of its nutritional composition. By that measure it ranks with soybean and peanut, the two most commercially important legumes, each grown on millions of hectares worldwide. Add to that its rugged constitution and ability to grow where other food crops cannot and the conclusion would seem that this is definitely a plant with prospects.

Within Africa

At first sight there doesn't seem to be much doubt about this plant's potential within its home range. On its web page, one South African university refers to marama as "a versatile legume and potentially high-protein, sustainable food crop for Africa." It also calls it the "magic marama bean, the green gold of Africa." But everyone should realize that there's many a challenge to be overcome before its promise is realized even in the lowest degree.

Humid Areas Although this is an extremely interesting species for any plant lover to work with, its prospects as a useful crop in the humid tropics do not seem high. Better-known tubers and leguminous seed crops—cassava, yam, peanut, and bambara bean, for example—are immediately available for this climatic zone.

Dry Areas Given its extreme drought tolerance, the marama offers the possibility of a new crop highly suited to the compelling needs of semiarid lands. In principle at least it should be tested in projects aimed at alleviating rural poverty and malnutrition in the drought-prone sandy zone of southern Africa.

Upland Areas The prospects here are unknown and uncertain. Any but the most preliminary tests are probably best left until more is learned about the plant and its wider prospects.

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[1] *Tropical Legumes; Resources for the Future*, 1979.

Beyond Africa

Marama will certainly grow beyond Africa. As noted, researchers in places such as the United States, Australia, and elsewhere have trialed it. But in such places it is likely to remain a marketplace curiosity, given the high performance of peanuts, soybeans, and similar crops.

USES

Like many of the species in this report, this plant has a surprising number of practical uses.

Seeds When taken straight from the freshly picked pod the seeds are soft and white and virtually inedible, being nearly tasteless and having an unpleasant, oily texture. Later, they harden, turn brown and become more appealing. They can then be eaten raw but most are first roasted, after which they have a delicious nutty flavor that has been compared to roasted cashew nuts. In this form they are very much liked by groups throughout the region. They are also often boiled with cornmeal, or pounded, mixed with hot water, and made into a delicious soup.

Oil Conventional presses or solvent extraction methods produce a clear and golden-yellow oil from the seeds. It has a pleasant nutty odor and agreeable taste, is similar to almond oil in consistency and appearance, and appears suitable for use in cooking and foods. It is a polyunsaturated oil and seems a good source of linoleic acid, one of the nutritionally essential fatty acids. The meal remaining after oil extraction has a remarkable 52-percent protein content, which could give it a place in local foods or feeds.

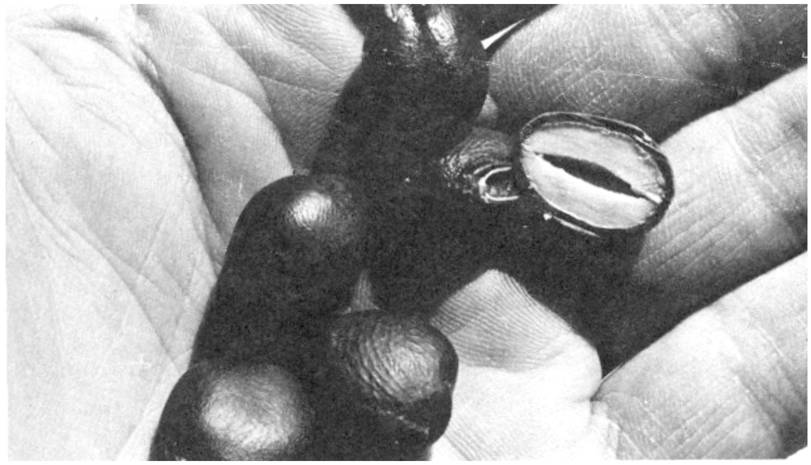
Tubers The succulent red-brown tuber, shaped like a giant top waiting to be spun, can attain enormous weights, as attested by the one in Botswana that achieved almost 300 kg. Normally, inhabitants of the Kalahari dig up young tubers when they weigh about 1 kg. Baked, boiled, or roasted whole, these have a sweet, pleasant flavor and make a good vegetable dish.

Feeds This plant is eaten by both people and animals. Livestock savor the beans, which are said to be especially good for fattening pigs.

Other Uses Wildlife relies on the plants for food and water. Because the gemsbok (a large antelope) eat the seeds and tubers with great relish, the plant is often called gemsbok bean.

NUTRITION

The marama bean analyses made so far have reported record protein contents of 30, 34, and 39 percent. Thus, the marama seed has a protein



Above ground, marama produces tasty seeds that rival peanut and soybean in nutritive quality. (B. Maguire)

content that rivals that of soybean (37-39 percent). Like most legume proteins, marama-protein is rich in lysine (5 percent) and deficient in methionine (0.7 percent).

An extensive study made at Colorado College showed marama essential amino acid content is also comparable to soybean. Indeed, its protein proved superior in nutritional quality to most common legume crops, such as garden bean and pea. It had more albumin and less globulin than soybean protein, making it more digestible and more readily available to the body.[2]

The seeds are a great source of food energy as well. Oil content is reported as 36-43 percent of the dry seed by weight. Thus, its oil content is about twice that of soybean, and approaches that of peanut.

The seeds are not only a good source of protein and energy but of nutritionally important minerals and vitamins, including potassium, phosphorus, thiamin, riboflavin, and nicotinic acid as well. They have less than half the fiber of peanuts, a feature both good and bad.

The edible underground portion of the plant is also nutritious, with tubers containing about 9 percent protein dry-weight.

HORTICULTURE

The plants are propagated by seed, which germinate readily in moist soil if scarified; soaking, however, rots them. Sprout-propagation has been done experimentally. Leaves often die back under drought or cold, but the storage root allows them to regrow quickly. This adaptation builds up root storage

[2] Bower, N., K. Hertel, J. Oh, and R. Storey. 1988. Nutritional Evaluation of Marama Bean (*Tylosema esculentum*, Fabaceae): Analysis of the Seed. *Econ Bot* 42:533-540.

and reduces moisture losses due to transpiration. Beyond this, little has been reported on the means of managing a sprawling marama crop. It may turn out that some growers focus on seed production, and others on tubers.

HARVESTING AND HANDLING

Currently, seeds are picked and tubers dug by hand. Raw seeds store well and remain edible for years. Roasting them in their shells makes them easy to open. Before eating, the beans must be carefully peeled.

LIMITATIONS

This plant is so neglected that the very lack of knowledge is perhaps its major limitation. Before wide-scale cultivation could be undertaken with any degree of confidence, information is needed on its adaptability to cultivation and on all aspects of its agronomy. Other limitations include the following.

While the plant has a wide distribution, it occurs patchily in very localized stands, perhaps indicating special soil requirements. Sand seems to be the common denominator. And that makes sense with a crop whose tuber needs to swell and not be restricted by soil pressure.

Even under good conditions, seeds may appear only after 2-4 years, and it may take as long for tubers to reach marketable size, after which they can become fibrous and astringent. Some tubers also have a tough, leathery skin.

Some writers have reported that the seeds can taste slightly bitter and that the hard shell surrounding them is a hindrance to their use as oilseeds. According to one correspondent, an excess of roasted seeds has a strong purging effect, but this is not widely reported.

Like soybean, the marama contains a potent trypsin inhibitor activity. This occurs in the protein fractions (both water-soluble and saline-soluble) and is destroyed by the heat of normal cooking.[3]

NEXT STEPS

Of course the marama is still a long way from being a cultivated plant. Even in their native region the bean is not a firmly established article of commerce. This means that there are many things to be done. In fact, this plant needs to be attacked on several knowledge fronts.

Protection Wild stands offer a wealth of different germplasm, but are being exterminated in many areas. For one thing, the land is being plowed and planted with maize or sunflower. For another, the seeds are being relentlessly harvested for village use and for sale. A third threat comes from the cattle ranching that now extends deep into the Kalahari region, as livestock eagerly devour the plant's leaves and runners.

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[3] Ibid.

Documented and approved germplasm collections should be made immediately and desirable strains selected. Initially, strains should be selected on the basis of productivity; to date, no single yield, measured or estimated, is reported. Vigorous strains producing large numbers of pods, bigger seeds, or more seed per pod could change the whole picture of the plant's future. Furthermore, strains that yield especially well under adverse conditions should be sought in the harshest sites.

In a related vein, the wisdom of the Kalahari peoples needs to be compiled in easily accessible form. As traditions are abandoned in favor of agricultural, pastoral, or industrial activities, their intimate knowledge of the bean and its use is being lost. Some of this has been done already, and those records need to be extracted from obscure and inaccessible reports and made accessible to plant scientists and others—*especially these peoples themselves*—who can help foster the marama's progress.

Use of the Wild Resource This plant seems an ideal tool for battling the scourge of desertification. This is a spreading species that sprawls across the land, protecting the soil from wind, rain, and sun. For the support of traditional cultures and ways of life, marama could be an outstanding tool. If production could be increased in the Kalahari, many would benefit.

Food Technology Storing and processing the seed (especially dehulling) needs better understanding. Temperature, loss of nutritional value, rancidity, and other effects on quality also need documenting.

The residual meal left after oil extraction contains about 50 percent protein and should be valuable for food and feed uses, but nutritional and analytical trials are necessary to undercover any undesirable factors.

Horticultural Development Marama bean is not yet ready for large-scale cultivation but agronomic research is nonetheless badly needed. Among features deserving investigation are the plant's requirements for altitude, temperature, moisture, soil type, fertilization, and latitude. Processes for enhancing growth also require documentation.

In addition, trials are needed for learning how to manage the plant as a crop. Cultural practices such as germination, spacing, planting, weeding, and pest and disease control all need study and evaluation.

Genetic improvement needs particular attention because today the plants produce too little seed for the fraction of the field they occupy.

Physiological Studies Because of this plant's special importance for semiarid climates, botanists could provide useful information by detailing the mechanisms that allow it to survive extreme heat and desiccation. Temperatures sometimes reach 50°C in its native habitat and surface water is available usually for only 8 weeks a year.

Below ground, marama produces a tuber much bigger even than sugar beet and much more nutritious even than potato or yam. Compared with those and other root crops it is high in protein, containing about 9 percent on a dry-weight basis. (A.S. Wehmeyer)

Tuber Development The tubers warrant particular attention: composition, growth rate, occurrence of nonastringent types, and production potential in small plots should all be investigated.

Harvesting In the long term the greatest barrier to development of this plant may prove to be the mechanical one of how to gather the crop, both seed and tuber, from this sprawling, awkward-to-handle plant.

SPECIES INFORMATION

Botanical Name *Tylosema esculentum* (Burchell) A. Schreiber

Synonyms *Bauhinia esculenta* Burchell

Family Leguminosae - Caesalpinioideae

Common Names

Afrikaans: Braaiboontjie, elandsboontjie pitte, gemsbokboontjie
English: gemsbok bean, gemsbuck bean, tamami or thamani berry
Thonga: marumama
!Kung: tsi, tsin
Khoi-khoi: gami
Herero: ombanui
Tswana: marama, marami, morama, lai, muraki, litammani, rama, tammani

Description

The plant is not a climber; it grows prostrate, sending viney stems creeping out over the soil surface in several directions. These runners are up to 6 m long and form a dense, geometrical pattern of overlapping whorls of stems, hugging the ground, presumably to avoid the drying winds. The vines carry double-lobed leaves that are soft and red-brown when young, turning leathery and gray-green with age. Golden-yellow, insect-pollinated blossoms develop in midsummer (December/January in southern Africa) and the fruits ripen in late autumn (April).

Each fruit comprises a large, flat, woody pod enclosing one to six large beans. The pod starts out soft and reddish-brown, then turns light green and, when ripe, becomes chestnut-brown and woody. Each bean has a hard inedible outer shell and an edible two-lobed seed inside. Though hard, the woody shell is thin, brittle, and easily cracked. The normally spherical seeds are roughly the diameter of a thumbnail and weight about 2-3 g. Their inner flesh is firm, cream colored, oily, and almost without fiber.

During cooler months, the stems may die back but the underground tuber remains viable and, with returning warmth, shoots forth more stems. After a few years the tuber can weigh more than 10 kg. It can contain 90 percent water by weight. Tubers more than two years old become fibrous and/or astringent. In deep, loose, sandy soils, the plant is reported to form “craters,” sometimes over a meter across. These hollows in the landscape are often ringed with stones that appear to have been forced to the surface by the giant tuber swelling beneath.

The plant is a legume but it belongs to subfamily Caesalpinioideae and, like many of them, it fails to nodulate and fix nitrogen.

Distribution

Within Africa Occurs in the northern part of Namibia, Botswana, as well as the western and northwestern Transvaal and the northern Cape in south Africa.

Beyond Africa Reported in California, Texas, and Florida in the USA, Queensland in Australia, and Israel, and some botanic gardens. It has curiously become a favorite of some bonsai enthusiasts, so probably now has a broader, yet still small-scale distribution.

Horticultural Varieties

None reported.

Environmental Requirements

The marama survives in regions where few conventional crops survive, yet it appears adapted to a wide range of climatic conditions. Obviously, the plant's environmental requirements are at present far from certain but the following seems a reasonable summary.

Rainfall Mainly, marama grows where rain is so slight and erratic that in some years almost no moisture falls at all. In some locations, even in the best of times, the rains last for only two months a year. The sparse precipitation arrives during short-lived torrential thunderstorms in spring and fall. The rest of the year remains almost rainless. Usually, however, there is subsoil moisture that the deep roots tap into. Indeed, in fine-grained sandy soils, water may remain in the root zone for months after rain. Marama also exists in well-watered locations receiving up to 800 mm annual rainfall.

Altitude The plant is found in a region lacking in mountains, but altitude seems hardly likely to be a limitation by itself.

Low Temperature In winter, when the plant is dormant, temperatures plunge very low (by African standards). Winter nights can be freezing and the days frosty.

High Temperature Very high summer temperatures to 47 °C in the shade and sometimes over 50° have been reported.

Soil Marama beans prefer neutral to acid soil. It is particularly prominent on the brick-red sand of the inland Namib Desert. Grows on deep sand but also where there are outcrops of dolomite; also has been grown on neutral shaly soils.

Related Species

Two related species may also be worth agronomic attention.

Tylosema fassoglense Grows from the Transvaal north through Central and East Africa to Sudan. This sprawling vine also yields edible seeds plus excellent livestock forage and a tuber with a wide variety of traditional medicinal uses. Like marama, the seeds are very high in protein (> 40 percent) and fats (> 30 percent), and widely appreciated.

Bauhinia petersiana A small shrub that grows together with the marama bean in open grasslands (as well as in sandy bushveld and woodlands) in Transvaal, Namibia, and Botswana, as well as in Angola and Zambia. The seeds can be eaten green, but ripe seeds are usually roasted, peeled, and pounded into a pleasant-tasting, coarse meal. The plant has been cultivated as an ornamental in South Africa and, given research, might also become a useful food crop for arid zones.

14

MORINGA

Although few Westerners have ever heard of it, moringa is potentially one of the planet's most valuable plants, at least in humanitarian terms. Perhaps the fastest growing useful tree, it commonly tops 3 m—or even 5 m—within a year of the seed being placed in the ground.[1] Some people actually grow it as an annual.

Strangely, this tree is raised for food rather than forestry. A sort of supermarket on a trunk, it yields at least four different edibles: pods, leaves, seeds, and roots. And beyond edibles, it provides products that make village life more self-sufficient: lubricating oil, lamp oil, wood, paper, liquid fuel, skin treatments, and the means to help purify water, to name but a few. The living tree, itself, also provides such things as shade, landscaping, and shelter from the elements.

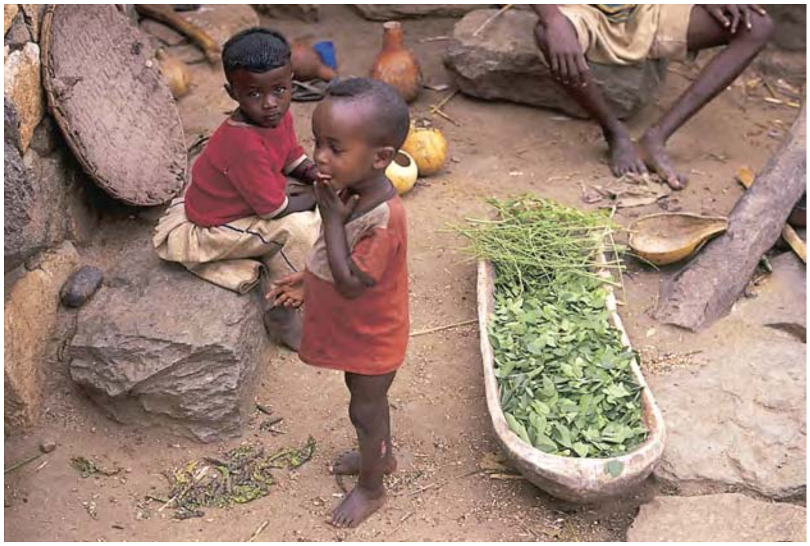
Arguably, this multi-tasking species is the most exciting tropical resource still awaiting widespread application. And it is a supreme poor-person's plant with promise for benefiting much of rural Africa. Not without reasons do aficionados refer to it as "mother's best friend."

Foreigners who have read about the seemingly wondrous moringa are usually disappointed when they finally get to see one. Except under the best of conditions, it is far from handsome. Indeed, it typically is small, scrawny, wispy, and wholly unimpressive to the eye. Partly that is because people forever pick it for food, but even the most pampered specimens will never be confused with the forest giants of popular imagination. All in all, this is a down-to-earth, unpretentious, and unsophisticated member of the tree world.

But this "working-class" species works, and it works well. Some varieties flower profusely and are used chiefly to produce young pods; others flower sparsely and principally yield leaves. In both cases production can be outstanding. A single tree grown under good conditions can, for instance, bear more than 1,000 pods a season and can supply leaves year round if the climate is conducive.

Of all moringa's edible parts, the green young pods are most sought-after. These legume-like fruits are typically 30-60 cm in length and are

[1] Roy Danforth wrote from Congo: "The trees grow much more rapidly than papaya, with one 3-month old tree reaching 8 feet. I never knew there could be such a tree."



Village of Kolme, Konso, Ethiopia. Moringa yields at least four different edibles: pods, leaves, seeds, roots. Next to the green pods, foliage is the most important food product. People in various countries boil up the tiny leaflets and eat them like spinach. Taken all round, this supreme poor-person's plant shows a remarkable capacity to help solve problems such as hunger, malnutrition, rural poverty, disease, deforestation, and visual blight. The leaves here are *Moringa stenopetala*, a cultural heritage and domesticated plant of the Konso people. In this region of southwestern Ethiopia its leaves constitute an important part of their diet. (E. Demeulenaere)

usually served as vegetables. Looking like giant string beans, but tasting somewhat like asparagus, they are highly nutritious. For one thing, they provide a good balance of all the essential amino acids. That alone is unusual in a plant food, but these pods also possess one of the highest vitamin C levels of any tropical vegetable, not to mention goodly quantities of vitamins A and B. And beyond all that they are among the best sources of minerals.[2]

Foliage is the next most important moringa food. People in many countries boil up the tiny leaflets and eat them like spinach—a spinach that nature has chopped to confetti size. In the Philippines, where moringa is exceptionally popular, these boiled leaves are commonly fed to babies. Nutritionally speaking, they are remarkable for methionine and cystine. Both are essential to health, and both are among the hardest amino acids for the

[2] A current summary and analysis of moringa nutrition, along with an overview and information on cultivation and food preparation, is Fuglie, L.J. 1999. Moringa oleifra: *Natural Nutrition for the Tropics*. Church World Service, Dakar; available on-line at churchworldservice.org/moringa/miracletree.html.

body to acquire from plant-based diets. Moreover, moringa leaves contain vitamins A and C, more calcium than most other greens, and so much iron doctors prescribe them for anemic patients.[3] And regular consumption of the leaves is reported to increase milk production among lactating women.

Because of discoveries like these a number of development organizations around the world are actively promoting moringa leaves and dried leaf powder as nutritional supplements. The leaves are remarkably easy to handle. Unlike many other leaf crops there is no fibrous leaf stalk (petiole) to be removed. The leaflets are thus 100-percent edible. And with more than three times the dry matter of spinach, they dry quickly and easily.

The thick, soft roots are probably moringa's third most important food resource. They are a popular condiment, with the flavor of horseradish, for which they are employed as a substitute. Other parts of this plant provide useful food items too. The shoot tips, flowers, and even whole seedlings make boiled greens that are similarly high in protein, vitamins, and minerals. Finally, the pods that are too old and tough to be eaten like green beans are employed as a snack—slit open and the sweet, frothy, white pulp sucked out.

Perhaps the most innovative and provocative use of this already innovative and provocative species is to treat water and wastewater. The protein found in moringa seeds can be used to settle silt and other contaminants. Research in Africa has disclosed that it can replace alum, a normally imported and expensive material. The water still needs a final filtration but the seeds make the process easier and more complete, while extending the useful life of water filters. This could be of major significance where water-borne diseases are prevalent and where central water treatment systems are creaky or nonexistent.

The genus *Moringa* is a small one whose center of biodiversity is the Horn of Africa.[4] The best-known species, *Moringa oleifera*, must have sprung from those East African "proto-roots" although it apparently completed its evolution across the Indian Ocean, in the foothills of the Himalayas. So although not African itself it derives directly from African stock. The following text relies mostly on this species (for the reason that it

[3] Researchers summarizing moringa put it this way: "...among the leafy vegetables, one stands out as particularly good. It is the horseradish tree, *Moringa oleifera*. The leaves of the tree are outstanding as a source of vitamin A and, when raw, vitamin C. They are a good source of B vitamins and among the best plant sources of minerals. The calcium content is very high for a plant. Phosphorus is low, as it should be. The content of iron is very good. They are an excellent source of fat and carbohydrates. Thus, these leaves are one of the best plant foods that can be found." Martin, F.W. R.M. Ruberte, and L. Meitzner. 1998. *Edible Leaves of the Tropics*, 3rd ed.; available via ECHONet.org.

[4] There are 13 species in the genus. Nine occur in eastern Ethiopia, northern Kenya, and Somalia (8 occur nowhere else). The densest concentration is Kenya's northeast corner, where 4 species are found. Two more occur in Madagascar and 1 is endemic to Namibia and southern Angola. Only 1 of the 13 species, *Moringa oleifera* itself, seemingly arose full-blown outside Africa. Information from Mark Olson.

is the only one about which much information is available). Nonetheless, it seems more than likely that the chapter's statements are at least generally relevant to *M. stenopetala* and perhaps also to the other species (see later), which presently remain all but unknown to experimental science and the technical literature.

Whether or not it has direct African roots, moringa could certainly prove beneficial to Africa. Taken all round, it shows a remarkable capacity to help solve problems such as:

Hunger An ability to provide so many different foods makes this tree potentially valuable for the needy and destitute. It yields up its bounty at little cost to, or effort from, the growers.

Malnutrition The pods and leaves are among the most nutritious foods to be found in the plant kingdom. In West Africa the leaves appear at the end of the dry season, when there are few other sources of leafy green vegetables. Several programs already promote production of moringa leaf powder for use in sauces or as a general food additive.

Rural Poverty Potentially there is profit in moringa. First, this is a fast-growing, high-yielding oilseed. Second, the trunk is gaining importance as a raw material for papermaking. And third, pods can be produced for the fresh market or for processing.

Public Health With its mother lode of vitamins and minerals, moringa is virtually a nutritional supplement for farm or village. Exceptional levels of iron and calcium should make it particularly valuable for women young and old. Adding to its public-health benefits is that its seeds can help purify water. There are also indications that seed extracts are useful treatments against skin complaints.

Deforestation This species is not a foresters' tree but its ability to thrive in wastelands and provide rapid shade cover could make it the choice for many tree-planting projects. Likely, too, it is a good nurse crop for slower-growing species that eventually will dominate the site.

Visual Blight Moringa is an excellent candidate for fast-track beautification of streets, slums, and squatter settlements. The average specimen looks like an arborist's nightmare, but a little care can endow it a pleasing rounded appearance. Interestingly, it might help de-uglify the megacities that are projected to dominate the future of the tropics, and make them more livable.

Overall, moringa is easy to use. It is particularly valuable for planting for

and by the young, the poor, and the landless—in schoolyards, parks, roadsides, bus stops, cemeteries, and so on. It likely has a special role in the camps for displaced persons now all too prevalent in many parts of Africa. This rugged, resilient species tends to produce well in marginal growing conditions and is a reliable source of greens in seasons and locations where few other vegetables can produce much of anything. In equatorial areas, it bears food almost year-round. With hunger, malnutrition, poverty, disease, deforestation, and visual blight so widespread, now is the time to bring this tree fully into the fold of African—nay, world—crops. Success seems likely to be not only quick but comprehensive.

PROSPECTS

Despite the previous neglect, this species seems poised to rise to take a major role in many facets of rural life in the world's warmer regions.

Within Africa

Humid Areas For the wet tropics moringa could be a most useful resource. This is not its traditional habitat, but the plant seems well adapted to hot, humid conditions and, at least in certain areas, has thrived under annual rainfall exceeding 3,000 mm.

Dry Areas Moringa is especially adapted to dryness and may resist several months of drought, probably because its swollen roots store water. It has survived, for example, blistering heat, desiccating drought, and depleted dunes in places such as Sudan and the Sahel.

Upland Areas Originally, moringa was recommended for planting only at altitudes below 600 m. However, the discovery of healthy stands at elevations of 1,200 m in Mexico and over 2,000 m in Zimbabwe has demonstrated that it is much more adaptable than supposed. It withstands light frost but is seriously harmed if temperatures dip 5°C below freezing for even one evening.

Other Regions

Some may at first balk at picking table greens from a tree, but for the hot and hungry corners of the tropical belt any such reluctance is likely to be temporary and will hardly keep moringa from quickly becoming invaluable.

USES

This living cornucopia can provide various means to a better life in the hot, harsh rural regions.

A rugged, resilient tree species, moringa tends to produce well in marginal growing conditions and is a reliable source of greens in seasons and locations where few other vegetables can produce much of anything. In West Africa the leaves appear at the end of the dry season, a time when other sources of leafy green vegetables have mostly died. Here, an older tree produces abundantly in the highlands of Oaxaca, Mexico (Mark Olson - explorelifeonearth.org)

Immature Pods As has been noted, the tender young pods have the general characteristics of a succulent string bean. They may be eaten whole but for ease of use most are sliced and diced before cooking. In India, these long thin vegetables are a common fare, frequently added to curries and even sliced, blanched, canned, and peddled in thousands of markets and stores. There is even an international trade in both fresh and canned pods. India, Sri Lanka, Taiwan, and Kenya for instance export them to Asia, Europe, and the United States, where they end up mainly in ethnic Indian groceries.

Mature Pods As the pods mature, they quickly turn tough. Even by the time they are as thick as a pencil they are often too fibrous to eat like string beans. In that form, they are called drumsticks, and are typically cut into pieces and the sweet frothy inside material is slurped out. Throughout India drumstick slices are well-known ingredients in pickles and in Madras they are common also in the famous drumstick curries.

Leaves The foliage is fernlike, with myriad tiny leaflets produced in abundance through most of the year. The feathery leaves are easily stripped to separate the leaflets, which are 1-2 cm in diameter. The young ones are particularly prized in the Philippines, where certain ethnic groups proudly associate their whole culture with the plant.[5] In addition to being boiled like spinach, they are dried, crushed, and sprinkled on food.[6] In many areas of Africa, people have found the leaves easy to preserve by air-drying (which should be done indoors since sunlight destroys vitamins A and C).

Seeds The soft seeds extracted from immature drumsticks are boiled and eaten like fresh peas. Fried, they taste like peanuts. Only immature white seeds are eaten (either boiled or fried). Once they ripen, the taste turns bitter.

Roots The pungent fleshy root is pulverized into a flaky condiment with a horseradish bite. This has given moringa the widely used name "horseradish tree." The thick, soft roots are also pickled. For this, they are peeled, dried, ground, and steeped in vinegar.

Seedlings Young seedlings are pulled up, boiled, and eaten whole.

Flowers The flowers, which occur year round in some places but are more often seasonal, are cooked as a vegetable and are sometimes steeped in boiling water to yield a fragrant tea. In Kenya's Kibwezi region, farmers fry the flowers and liken the taste to that of fried egg.[7] Raw, they have a strong or hot radish-like flavor. In Oaxaca, Mexico, poor people have adopted the tree solely as a source of white flowers for decorating churches and houses on religious festival days.

Honey A good bee tree, moringa begins flowering at a young age. Specimens from seed usually flower within 2 years; those grown from

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[5] One example is the Illocano people of northern Luzon.
[6] One West African hospital is drying and powdering the leaves, then giving the powder as a prescription when a malnourished child comes in. Parents are instructed to mix it with the baby's food. Such usage is also spreading quickly elsewhere.
[7] Information from D. Odee.

With its mother lode of vitamins and minerals, moringa is possibly the planet's most valuable undeveloped plant, at least in humanitarian terms. Regular pruning can maintain a compact form whose leaves are easily harvested (left). New leaves are produced in abundance almost daily (center), or plants can be managed to produce pods (right). Intensive management such as this can give impressive, sustain yields in a small space. (Neofarming - moringa.com.tw.)

cuttings have been known to flower when only a few months old.[8] Then, as long as the climate is conducive, they bloom continually for years on end. The resulting honey is tasty, clear, and often consumed as a medicine.

Fodder Livestock relish the foliage so much that in some regions moringa is an important fodder. In India, for example, water buffaloes are fed the chopped up leaves and branches, which are said to boost milk production. Trials conducted in Nicaragua found that range-fed cows gave a 30-percent increase in milk and meat production when their diet was supplemented with 45 percent moringa forage.[9]

Oil Pressing the seeds produces a pale-yellow oil. Alternately, seed can be boiled in water, in which case the oil floats to the surface where it can be skimmed off. Oil makes up 20-40 percent of the seed—a reasonable quantity. It is a valued base for ointments since it lacks color, smell, and taste, and turns rancid only slowly. These same properties make this non-drying oil useful for enfleurage, the process by which perfume companies extract flower fragrance. Because it absorbs and retains delicate scents, it is also valued in products like hair oil. It was once traded internationally ("ben oil") for lubricating the wheels of clocks as well as making oil paints for artists. More recently, it has shown particular value for making quality soap.

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[8] In Kenya moringa has flowered **and fruited** in 3 months. Information from D. Odee
[9] Information from L. Fuglie.

Fuel Moringa oil is said to equal the best lamp fuel, burning with little scent or smoke and emitting a light both bright and clear.

Gum When wounded, the bark exudes a polysaccharide used like glue.

Wood Although soft and spongy and not a great fuel, the wood burns cleanly and gives off little smoke or smell. White and tasteless, it also makes good chopsticks, and provides a pulp suitable for newsprint as well as wrapping, printing, and writing papers, not to mention the viscose rayon used in textiles and cellophane.

Shelter, Shade, and Privacy Screens Though never showy, this tree is not unattractive. People sometimes plant it to ornament gardens as well as highway verges. Its airy foliage casts only light shade. Planting a line of seedlings produces a living fence that can become a seamless line in as little as a year. For even faster results, sizable branches can be set upright in the ground to form an "instant hedge."

Agroforestry The tree is good in agroforestry and mixed cropping. The thin shade helps protect vegetables in the hot tropical sun. Because of its downward rooting pattern, there is little competition with associated crops.[10] In sum, this seems to have the making of an ideal agroforestry component.

Water Purification Inside each pod are found up to 25 seeds, which yield a quality vegetable oil and in crushed form they can be used to help clarify turbid water. Charged proteins in the seed tissues coagulate suspended particles, precipitate disease organisms, and generally help turn a dangerous muddy muck into a clear potable liquid.

Medicinal Uses Many supposedly effective folk remedies incorporate moringa. The pulp of the root, for instance, is used like a "mustard plaster." The crushed seed has been recommended as an ingredient in ointments because it demonstrates anti-microbial activity.

NUTRITION

Most parts of this plant are more than just edible; they are nutritious.[11] Moringa, unlike most foods in this report, has been analyzed in many studies that support high (though highly variable) levels of carbohydrate, protein,

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[10] Information from D. Odee.

[11] Much information in this section is based on the detailed review of Fuglie, op. cit., and Gopalan, C., B.V. Rama Sastri, and S.C. Balasubramanian. 1971. *Nutritive value of Indian foods*. National Institute of Nutrition, Hyderabad (revised and updated in 1989 by B.S. Narasinga Rao, Y.G. Deosthale, and K.C. Pant).

and especially vitamins and minerals. It has been said, for example, that: "As sources of the usually short sulfur-bearing amino acids methionine and cystine, *Moringa oleifera*, grown for edible leaves, shoots, young fruits, and roots, is incomparable."[12] Methionine and cystine are arguably the most critical dietary ingredients for people lacking regular access to meat, milk, cheese, eggs, or fish.

Leaves Leaves are eaten fresh or dried as a storable powder (in which process they can lose much of their vitamin C). On a dry-weight basis, both have more than 200 calories (up to 400 is reported), with about 30 percent protein and 1-2 percent fat. Nutritional trials with laboratory rats show that the leaf is an excellent supplement to rice and other staples. In addition to being rich in overall protein these leaves also, as noted, provide methionine and cystine. A modest helping (100 g dry-weight) generally provides at least an adult's daily requirement for provitamin A. The leaves are also supply good folate and other B vitamins. Further, they are among the best plant sources for dietary minerals, especially calcium (up to about 2000 mg) and iron approaching 30 mg, about twice the level of spinach and exceeding even the amount in patent medicines touted for stimulating pep and vigor.

Pods On a dry-weight basis the protein content of moringa pods ranges from 20 to 30 percent—an amount well above average for a vegetable. Moreover, vitamin C content is so high that a 50 g serving (or less) provides an adult's daily needs. In addition, minerals seem to be in good proportion. Iron—often deficient in African diets—is as high or higher in the pods than in the leaves, although the level probably depends on site conditions and preparation. The content of copper also seems notable (though highly variable and requiring confirmation).

Seed Oil The liquid making up a quarter to almost half the seed's weight is not unlike olive oil in composition. In one analysis of the fatty acids, the seed oil contained about 66 percent oleic, 9 percent palmitic and behenic, and 7 percent stearic.[13] The nutritional contribution of the oil itself to meager diets could be significant.

HORTICULTURE

This tree generally grows satisfactorily, but just how to grow it best is far from certain. Outside certain regions of India, where large-scale cultivation is practiced, the tree receives little professional horticultural attention and has not been subjected to formal comparative trials.

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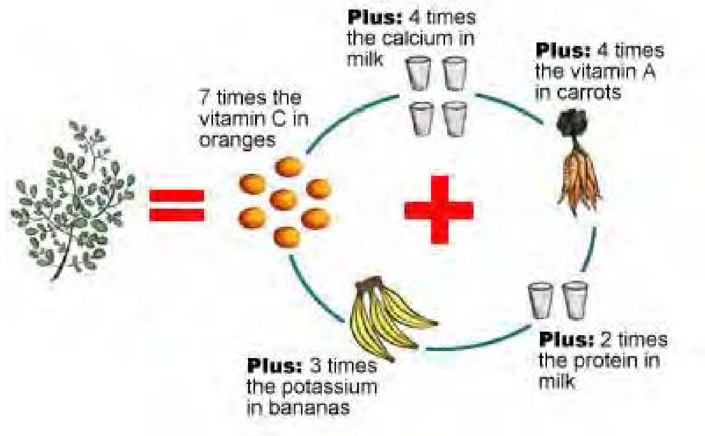
[12] Martin et al., op. cit.

[13] Sastri, B.N., ed. 1962. *Wealth of India: Volume VI.* Council of Scientific and Industrial Research, New Delhi.



Gram for gram, fresh moringa leaves outperform these well-known nutritional champions, and they taste good too. (TreesForLife.org.)

Moringa can be propagated through seed. No pretreatment is required and seeds sprout in only a few days in prepared seedbeds, a week or two in the field. However, this species is mostly (and most easily) propagated via cuttings. Even sections of branches as long as an arm will root in moist soil, becoming tree-like in just a few months and producing fruit within a year. However, trees grown from cuttings tend to have short and spreading roots.

Mulching and fertilizing improve production and quality of the leaves. In addition, heavy pruning encourages lateral shoots and increased leaf production. Pruning tops (at about head height) provides for easy harvest.

By and large, diseases or pests seldom affect the tree seriously. In India, a foot rot (*Diplodia*), a bark disease (*Indarbela*), and a defoliant are reportedly problematic. Also, caterpillars sometimes leave the tree leafless and termites sometimes tunnel into the trunk. Termites (*Macrotermes* spp.) can kill mature trees, especially during prolonged droughts. When planted in very wet conditions, it may suffer root rot.

A contributor has passed on advice for making eye-catching moringas: “This awkward tree can actually be quite attractive if the tip is pinched out when the tree is perhaps 2 meters tall, and the side shoots likewise pinched when they have grown some. This forces a rounder canopy. We grow it that way and use it as a light shade for vegetables that do not do well in the full tropical sun.”

HARVESTING AND HANDLING

The tree withstands heavy cutting and can provide a continuing supply of wood, fodder, and other products. Both coppicing (continual cutting near the

base) and pollarding (continual cutting higher up the trunk) are possible. One recommended system is to set the trees about a meter apart and trim them regularly like a hedge to provide successive crops of leaves.

Plants raised from cuttings bear in 6-8 months after planting. The pods are usually taken directly from the trees individually by hand.

The leaflets are easy to harvest by stripping them off between thumb and forefinger. As already noted, there is no leaf stalk to be removed and the leaves dry quickly and easily.

LIMITATIONS

Many (even most) of the trees now scattered throughout the tropics are pale shadows of the top-performing types. Plants raised from seed often produce inferior pods because of intercrossing with bitter-tasting wild types. Thus for quality crops, vegetative propagation is a must.

The pods must be picked at the right stage because within a day or two they toughen up and turn stringy. Unfortunately, it is not easy to tell (in words) exactly when a pod is at the point where it is ready to pick.

Termites in some areas may limit the tree's culture. Leaf-cutting bees sometimes strip a tree of almost all its greenery. Browsing animals are also a threat. Both livestock and wild herbivores consider moringa to be like candy, and can destroy a new planting overnight. Pigs have been known to dig out even established trees to feast on the tasty roots.

The tree's limbs are weak and break off easily, especially when laden with pods. The soft, almost spongy wood is slow to dry and very susceptible to termite attack, so it is not useful in construction.

The horseradish substitute from the roots must be made with care because the bark evidently contains alkaloids. To eliminate any possibility of toxicity, careful peeling is needed. Indeed, this usage as a peppery condiment may not be safe at all.

NEXT STEPS

Any tree that can provide food to the hungry parts of the planet could be the subject of massive plantings and major initiatives. Such projects need to be undertaken; some are already in action and have much to teach that is positive. In West Africa, Church World Service (CWS), has helped establish over 70 hectares of moringa plantings and is creating a farm for intensive production of leaf powder. In Tanzania, Optima of Africa is growing thousands of hectares of moringa for production of oil and of the flocculent used to clarify water, and Trees for Life has projects in many Asian and tropical American countries. A quick Internet search reveals many others.

Publicity With all the potentials, it is hard to imagine why there aren't million-dollar moringa-promotion programs with international backing.

Foresters probably shun it because it is basically a food crop; agronomists because it is a tree; fruticulturists because it is a vegetable. The combined neglect has reached such a pass that in many countries hungry people don't even realize that the moringas growing around them are edible. Even where millions are malnourished or starving the plant's nutritious products often are wasted. Haiti and Sudan are just two examples where this good food goes begging. In both cases the tree was introduced as an ornamental and the fact that it provides life-giving nutrients remains mostly unrecognized. Local and international efforts are needed to provide information, publicity, and greater awareness of this tree and its capabilities—particularly to the people on the ground and their supporters.[14] Introduction of good genotypes for multi-location testing is also required.

New Plantings In each of the several dozen appropriate countries—especially those facing chronic malnutrition—a rapid search (rather than a time-wasting, exhaustive one) should be made for adequate moringa types, which should then be vegetatively propagated and planted out in nurseries and observational trials. A few groups are already way ahead on this and have such trees already selected and planted out. The Kenya Forestry Research Institute, for instance, has initiated such a program and is also developing seed orchards of improved material for specific purposes and end uses.[15] But many more groups across many African countries should be also exploring this most promising resource.

From these "foundation banks" seeds or cuttings can be taken and distributed to farmers, homeowners, and others. In all of this there are good chances for both humanitarian success and small-business development. Moringa cultivation should be particularly promoted in the slum areas of cities, where small plantings should prove of immediate benefit to children (see below).

Nutritional Interventions Throughout Africa, moringa could be immediately incorporated into programs tackling the misery of malnutrition. It is reported by CWS that three spoonfuls of moringa leaf powder (about 25g) contain 300 percent of a typical toddler's daily vitamin A requirement, along with 42 percent of the protein, 125 percent of the calcium, 71 percent of the iron and 22 percent of the vitamin C. It also contains a full complement of minerals and amino acids.

With four times the beta-carotene of carrot, moringa has especial potential for programs dealing with avitaminosis, the vitamin A deficiency

[14] Moringanews (moringanews.org) is one such international network of people interested in moringa; their website offers a wide variety of documentation on moringa, and a platform to exchange knowledge, products, and services.
[15] Information from D. Odee.

Moringa produces seed in abundance. Immature seed is relished fresh, boiled, or fried. Mature, it yields a very pure oil widely used in cooking as well as for energy and quality lubrication ("ben oil"). The remaining meal has proven to be a powerful home-grown water-purifier whose use is rapidly expanding in many parts of rural Africa. (Neofarming - moringa.com.tw.)

that causes 70 percent of childhood blindness.[16] Other diseases caused by the lack of nutrients that are abundant in moringa include beri beri, rickets, and scurvy. There's already some precedent to follow: Since 1996, for instance, CWS and local partners have been actively promoting moringa for improved nutrition in Senegal. Based on CWS research funded by the U.S. Agency for International Development, many health centers now stock moringa leaf powder in their pharmacies for use in treating cases of moderate malnutrition.

The seed oil could become a valuable nutritional commodity with the ability to extend diet and provide cooking oil from a readily available local source.

Horticultural Development While such major initiatives are under way, more basic studies are also needed to provide better materials and more reliable guidelines for long-term use. Three examples are:

Genetic Improvement Almost certainly moringa can be selected and improved in ways that produce separate cultivars for top-quality vegetable

[16] The International Eye Foundation is using moringa this way in Malawi.

oil as well as for various tasty and nutritious vegetables from fruits and leaves. Hybridization between elite types might also be carried out. Elite cultivars of course require vegetative propagation. In India, over 85 types of moringa have been developed to reflect local tastes in pod size and shape. Many of these types are grown for one to three years, and then replaced with new trees on a regular rotation, almost as if they were biennials.

Genetic Diversity This immensely useful tree's genetic variability needs careful assessment. Although many types exist, no one presently knows which are best suited to various uses, environments, and local needs. Much genetic diversity is especially available in the Terai region of India and Nepal, as well as Uttar Pradesh in northern India. Surprising genetic diversity has also been located in century-old material in eastern Africa.[17]

Agronomy There needs to be more exploration into the most favorable conditions for cultivating moringa. The plant seems to grow well under many different conditions and in many different soils, but no one knows its optimal requirements or its limits.

Water Purification Lack of drinkable water is, arguably, the world's biggest health threat. In the rural regions of many developing countries, people must take drinking and washing water from rivers, wadis, swamps, lakes, and even hollowed-out tree trunks. Using moringa seed to clarify such supplies should be more widely tested and, where appropriate, used. The science behind it has already been pinned down enough to proceed in this way. Two groups have already made spectacular advances in our understanding of the process.[18]

One of these pioneers has discovered that oil plays no part in the water-clarification process. He now recommends introducing small-scale moringa-seed extraction in the rural areas. Pressing the seeds provides the valuable oil *as well as* the presscake (solids residue after oil extraction) containing the charged proteins that effect water clarification. He now sees the coagulant as the byproduct of high-quality oil extraction.[19]

Other Uses The economic feasibility of employing the wood for paper pulp deserves pantropic exploration. By most standards the wood is poor, but the tree grows fast and might become extremely valuable wherever other

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[17] Information from D. Odee.
[18] These groups have worked extensively in Africa, but are centered at the Deutsche Gesellschaft für Technische Zusammenarbeit in Germany (Samia Al Azharia Jahn) and the Engineering Department, University of Leicester, Leicester, United Kingdom (Geoff Folkard). In addition, Rotary Clubs are sponsoring moringa-based water-purification projects in Brazil and Zimbabwe.
[19] Information from G. Folkard.

pulp sources are scarce. Indeed, large-scale moringa plantings are already being established to help meet India's paper shortage. In sub-Saharan Africa there are large tracks of dryland suitable for moringa, but not conducive to other crops; these might perhaps be planted to moringa, thereby protecting the environment as well as generating useful resources, including pulp.

Moringa is potentially useful in alley cropping and contour hedges grown across hillslopes to slow soil erosion. Specimens grown from seed are deep rooted, with few lateral roots to interfere with the neighboring crop plants.

Exploration of the Wild Resource Although the Horn of Africa is the "birthplace" of the genus, only recently have significant efforts been made to explore the *Moringa* species to be found there and the uses to which they are put.[20] In fact, the traditional cultivation of the "cabbage tree" (*M. stenopetala*) was apparently "lost" to science until mentioned for the first time in a geographical paper concerning Ethiopia as recently as 1938. Even today, the tree is maintained inside compounds as well as on terraces, and its leaves are an important vegetable during the dry season. Yet it has never been subject to scientific investigation.[21]

Food Technology In the handling and processing of moringa products, much remains to be done before the tree's full potentials can be approached, perhaps even in India. Examples of two needs follow.

- *Cooking Oil* Many Third World families would benefit enormously if they could grow a quality cooking oil on trees in the backyard. Moringa may not prove the best candidate, but this possibility ought to be explored. Typically oilseeds need to be heated to free up the oil before they are pressed, but this has been found unnecessary in the case of moringa seed—friction generates sufficient heat.[22] This is a boon in that it removes one cumbersome and costly step, and it also means that the oil may be classed as "cold pressed" and touted as a "natural, pure vegetable oil."
- *Seeds* Tests should be done to determine the range of nutritional values for the seeds (and pods), and the potential production of animal feed from the seed meal (the solid left after the oil has been expressed).

Medicinal Uses Moringa is renowned for supposed medicinal properties. A few investigations have suggested there may be some merits to the claims.

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[20] Mark Olson's modern moringa explorations are outlined at explorelifeonearth.org/moringahome.html.

[21] The growers are mainly the Konso, Burji, and Gidole tribes in the highlands south of Lake Chamo in Ethiopia and the Konso and Burji minorities in the Marsabit District in Kenya.

[22] Information from G. Folkard. "One advantage," he writes, "is that if a small extractor is used no external heat is needed."

The root bark, for instance, contains two alkaloids—moringine and spirochine—that act on the nervous system. The roots contain pterygospermin, which inhibits growth of gram-positive and gram-negative bacteria.[23] An old report from Southeast Asia says a decoction of bark stimulates menses and is used for "morning after" birth control. In parts of West Africa, moringa leaves or juice are taken for diabetes and high blood pressure. Some or all of these might have merit, but only careful analysis, sound research, and (if warranted) trials involving control groups and statistical analysis will answer that. Initial investigations seem worthwhile.

SPECIES INFORMATION

Botanical Name *Moringa oleifera* Lamarck

Synonyms *Moringa pterygosperma* Gaertner; *Moringa zeylanica* Pers.; *Guilandina moringa* L.

Family Moringaceae

Common Names

English: moringa, horseradish tree, drumstick tree, sujuna, ben tree, ben oil tree,
French: ben ailé, ben oléifère, benzolive, arbre radis du cheval
Spanish: ben, árbol del ben, paraiso, morango, moringa
Portuguese: acácia branca, marungo, muringa, moringuiero; cedro (Brazil)
Arabic: ruwag, alim, halim, shagara al ruwag (Sudan)
Swahili: mzunze, mlonge, mjungu moto, mboga chungu, shingo
German: Behenbaum, Behenussbaum, flügelsaniger Bennussbaum, Pferderettichbaum
Italian: sàndalo ceruleo
Fon: kpatima, yovokpatin,kpano,yovotin
Gun: èkwè kpatin, kpajima
Yoruba & Nago: èwè igbale, èwè ile, èwè oyibo, agun oyibo, ayun manyieninu, ayèrè oyibo
Adia: kpashima
Mina: Y\yovo vigbe, yovo kpati
Bariba: yuru ara, yorwata yoroguma
Saxwe: kotba

[23] Few studies have been conducted to validate scientifically their popular use, but two Guatemalan doctors reported making an ointment that proved as effective as neomycin in clinical trials. They used seed from moringa. Ointment can be prepared by extracting the active seed ingredient with very inexpensive equipment and mixing with petroleum jelly. Information from ECHONet.org.

Waama: yori ku-oununfa
Fulani: gawara, konamarade, rini maka, habiwal hausa
Hausa: zogall, zogalla-gandi, bagaruwar maka, bagaruwar masar, shipka hali, shuka halinka, barambo, koraukin zaila, rimin turawa
Ibo: Ikwe oyibo
Tonga: mupulanga, zakalanda
Wolof: neverday, nébéday
Philippines: malunggay or malungai (Tagalog)
India: sujuna, sajina, lopa, horseradish or drumstick tree
Senegal: nebeday
Haiti: benzolive (Haitian Creole)

Description

Moringa is a medium-sized tree that attains about 10 m in height. It has a straight trunk (10-30cm thick) with bark that is whitish or gray, corky, with longitudinal cracks. It also has a tuberous taproot, whose presence helps explain the species' tolerance to drought conditions.

Normally umbrella shaped, the tree comes with a lax crown of graceful, airy foliage, whose feathery effect is due to the finely tripinnate division of the leaves. Those leaves are densely crowded at the tops of the branchlets. Depending on climate the foliage is evergreen or deciduous and, from a distance, reminiscent of a legume like leucaena or calliandra.

In season the tree is enshrouded in creamy white, honey-scented flowers arranged in drooping panicles 10-30 cm long. Flowers are insect pollinated and "require a large number of insect visitations," with carpenter bees the most common guests.[24] Flowers and fruits (pods) can occur twice a year; in many places flowering and fruiting occur year-round.[25] The fruits are initially light green, slim, and tender, eventually turning dark green and firm. Depending on genotype, they are up to 120 cm long. While most are straight a few are wavy and some curly. In cross-section most are rectangular but a number are triangular and some are round. Fully mature, the dried seeds are surrounded by a lightly wooded shell with three papery wings.

Distribution

Africa. Although widespread in Africa, moringa is seldom cultivated intensively and in only a few places is selected and put to use in anything like an optimal manner.

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[24] Bhattacharya1, A, and S. Mandal. 2004. Pollination, pollen germination and stigma receptivity in *Moringa oleifera* Lamk. *Grana* 43(1):48-56. The authors list pollinators as Thysanoptera (thrips), Hymenoptera, Lepidoptera, and Coleoptera, and note that delayed stigma receptivity favors cross-pollination.
[25] It is said that in the gardens of southern Florida the only tree that flowers every day of the year is moringa

Beyond Africa Moringa has long been cultivated in rural areas throughout the Indian Subcontinent as well as much of Southeast Asia. It is, for example, naturalized in Sri Lanka, India, Malaysia, and the Philippines. In addition it has been introduced to the West Indies and tropical America (from Mexico to Peru, Paraguay, and Brazil).

Horticultural Varieties

This crop has not been systematically improved, but several named cultivars with individual qualities are known in India. One called 'Bombay' has curly fruits and is considered among the best. Another, 'Jaffna,' is noted for having fruits 60–90 cm. A third, 'Chavakacheri murunga,' is known for its exceptionally elongated pods (90-120 cm long). Finally, there are the so-called baramassi varieties, which tend to flower continuously because they have been selected through the ages to provide buds, flowers, and fruits for food throughout the year. These jack-of-all-trades types are especially suitable for subsistence use. There is also a dwarf variety known as 'PKM1,' bred for the short stems that make it easy to harvest the pods, which are exceptionally long. Some Indian varieties are showing exceptional promise at the International Institute of Tropical Agriculture in Nigeria.

Environmental Requirements

Moringa is an extremely adaptable species. It grows fine throughout the warmer life zones, ranging from subtropical through tropical and from dry savanna to rainforest.

Rainfall While preferring moist situations (such as along waterways and coastal areas), it adapts to climates with several months of drought. Moringa is reported to tolerate annual precipitation of 250-1,500 mm.

Altitude Elevations below 600 m are reported best for moringa, however it thrives at elevations over 1,100 m in protected tropical uplands (southern Mexico and Dire Dawa, Ethiopia, western Kenya near Lake Victoria, for example).[26] Indeed, in some tropical areas it has been recorded growing at 2,000 m. In Ethiopia the related species *Moringa stenopetala* is regularly found at altitudes up to 1,800 m.

Low Temperature The tree is reported to tolerate light frosts without significant damage. Even when a freeze kills a mature tree back to the roots, it usually quickly sends out new growth from the ground. A good overall temperature range is 20-30ºC.

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[26] In Oaxaca State, Mexico, moringa is cultivated at altitudes up to 1,200 m in sheltered locations. The highest site with abundantly flowering and fruiting moringa trees was at San Juan Gegoyache in the valley of the Totolepan River.

High Temperature No upper limit has been reported. It is known that moringa can take up to 48ºC for limited amounts of time.

Soil The tree survives on all types of soils, including the heavier clays. However, it grows best on sandy sites and alluvial lands. The soil (especially the clay ones) must be well drained because the tree is sensitive to waterlogging. It can be established in alkaline soils (up to pH 9) and acid ones (pH 4.5).

Related Species

As we've noted, out of the 13 *Moringa* species only *M. oleifera* has been accorded research and development. The rest remain almost unknown to science.[27] Perhaps they could provide even better food ingredients, flocculants, antibiotics, oils, or wood. Perhaps they have their own unique qualities. No one knows at present.

Of these ignored species, one stands out. Unequivocally African, *Moringa stenopetala* was domesticated in the East African lowlands. Many different ecotypes and cultivars are still found in Ethiopia, for instance. The plant has been called cabbage tree and it is very similar to moringa except that it is more drought tolerant and the leaves and seeds are larger. Some claim that its leaves are even tastier than moringa's.[28] In addition, this species is said to be even more promising as a coagulant for water clarification.[29] For all that, though, it is barely known to anyone but the villagers whose ancient ancestors first put it to use.

A third species, *Moringa peregrina*, is another Horn-of-Africa native. It is used as a condiment and for several other purposes in West Africa but in modern times remains almost unstudied. That was not so in the past, however. Its fruits have been found in many Egyptian tombs and it is

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[27] The species are: *Moringa drouhardii* (Madagascar), *Moringa concanensis* (mostly India), *Moringa arborea* (northeastern Kenya), *Moringa hildebrandtii* (Madagascar), *Moringa oleifera* (India), *Moringa borziana* (Kenya and Somalia), *Moringa ovalifolia* (Namibia and extreme southwestern Angola), *Moringa peregrina* (Horn of Africa, Red Sea, Arabia), *Moringa longituba* (Kenya, Ethiopia, Somalia), *Moringa stenopetala* (Kenya and Ethiopia), *Moringa pygmaea* (northern Somalia), *Moringa rivae* (Kenya and Ethiopia), *Moringa ruspoliana* (Kenya). Information from Mark Olson.

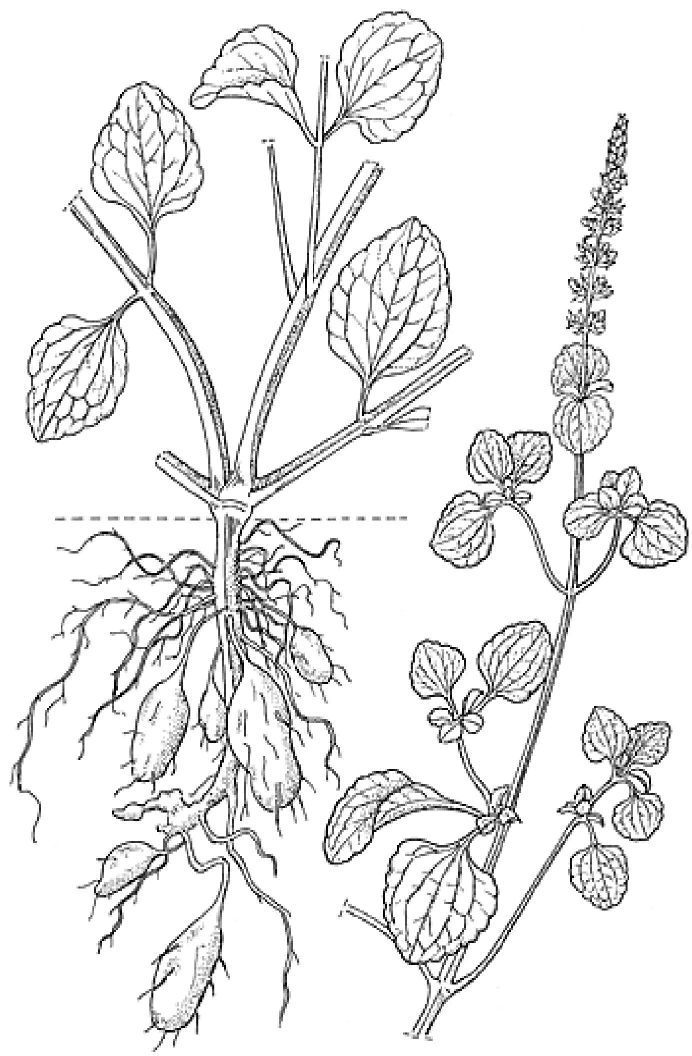
[28] Michael Madany wrote from Somalia of a comparison trial. "In spite of the initial rapid growth of *Moringa oleifera*, in drier years the species has not done well without some watering. *Moringa stenopetala*, by contrast, has the lushest foliage and continued to grow during the exceptionally long dry season from last August until this April. We began cooking leaves and young shoots in April (taste of the two species very similar). We obviously aren't eating it fast enough, since two large limbs have fallen under their own weight."

[29] The Maasai Njemps, a tribe in Kenya, use its seed to clarify the turbid water from Lake Baringo. Information from D. Odee.

frequently mentioned in ancient Egyptian texts for its oil and medicinal applications.[30] This species (a widely used synonym is *M. aptera*) provided the original ben oil (the name deriving from the Arabic *al Bân*), an odorless sweet oil that keeps well and is esteemed in perfumery. This species is still found today in Egypt and in Israel's Rift Valley as far as the southern shore of the Dead Sea. It has wood that is good for firewood and charcoal, and also reportedly resists termites.

There is also the potential for hybridizing *Moringa oleifera* with other members of its genus. *M. stenopetala*, for example, has been shown to contain flocculating agents that show a high homology to those in *M.oleifera*. With *M. stenopetala* producing bigger seeds (but usually a lower yielder) than *M .oleifera,* it may be possible to increase overall seed yield through such hybridizations. It may also be possible to increase the oil yield of *M .oleifera* by producing a hybrid with *M. peregrina*, whose seeds yield approximately 50 percent oil.

[30] Many believe the Biblical book of *Exodus* (15:23-27) is the earliest written reference to what is most likely *Moringa* being used to purify water (probably *Moringa peregrina*,): "And the people murmured against Moses, saying, What shall we drink? And he cried unto the Lord; and the Lord shewed him a tree, which when he had cast into the waters, the waters were made sweet…."



Drawing courtesy of PROTA.org

15

NATIVE POTATOES

People have eaten tubers since time immemorial. Indeed, a small but ardent band of anthropologists argues that cooked tubers in general played *the* critical role in separating humankind from the rest of the primates. According to them, the (presumably African) tubers provided foodstuffs that did not have to be chased down and required little chewing. Cooking turned the starch into sweet, appealing foods and easily absorbed calories. In addition, the tubers needed to be kept in one place under protection, so they initiated "home life." All of this—according to the proponents—prompted the evolution of large brains, smaller teeth, modern limb proportions, and even male-female bonding.

This may seem like a big indictment to pin on a few homely plants, but Harvard anthropologist Richard Wrangham and his colleagues are convinced that cooked tubers were pivotal in this way to human evolution. They don't speculate on which species led to the creation of humanity, but the subject of this chapter seems a leading possibility.[1]

Even today, Africa depends heavily on root foods. Indeed, without the contributions from cassava, potato, sweet potato, and yam, hunger would spin out of control all across the continent. Of those four cornerstones of the current food supply, however, only yam is native.[2] Yet Africa has a wealth of indigenous edible roots and tubers. Sadly, they are among the most "lost" of Africa's lost food crops.

Elsewhere in this book we describe marama and yambean, both of which are African legumes grown at least partly for tubers. Here we highlight the so-called "native potatoes," two plants grown *solely* for tubers. In culture

[1] Assuming that modern vegetation reflects what was in southern and eastern Africa almost 2 million years ago, the only other likely candidates are yam, marama, yambean, *Vigna vexillata* (a fascinating legume), and maybe tiger nut (*Cyperus esculentus*). Lesser-known possibilities from the region where humanity arose include sweetpotato relatives (*Ipomoea* species), water root (*Fockea* species), *Raphionacme burkei*, and a couple of cucurbits, *Coccinia rehmannii* and *Coccinia abyssinica*.

[2] Both cassava and sweet potato are of tropical American origin and were introduced probably in the 1600s by Portuguese slavers needing to feed masses of people crammed aboard tiny ships. Potato arrived in the African highlands relatively recently, within colonial times.

Although closely related to the *Coleus* and *Plectranthus* grown in gardens around the world, African potatoes (*Solenostemon rotundifolius* shown here) are grown for what's out of sight: tubers that can form an nutritious part of their diet. From West Africa south, tubers from different species of these edible mints have been grown for generations, but they are only now coming to the attention of scientists and development workers. (James Allermann)

and usage, these two are more akin to the conventional root crops.

Despite the name, the plants of this chapter[3] are neither potatoes nor potato relatives. Nor are they related to sweet potato, yam, or cassava. They are members of the mint family. This 3,000-member family graces human existence with numerous herbs and fragrances, including lavender, mint, spearmint, rosemary, sage, thyme, oregano, basil, and majoram, but no major root crops. Indeed, Africa's native potatoes are the only mints producing human food below ground.

Both these native potatoes are herbaceous perennials. Speaking generally, they are distributed from the warmer eastern regions of South Africa northwards to Ethiopia and from there westward as far as Senegal. The occurrences mostly overlap, however one native potato (*Solenostemon*

[3] Although this chapter deals with two species, botanists have over the centuries given different scientific names to native potatoes collected from different corners of Africa. Their taxonomic classifications depend on tiny differences in the flowers that may or may not reflect genetic differences big enough to block mutual fertility.

rotundifolius) is traditionally produced primarily in West Africa while the other (*Plectranthus esculentus*) is a resource primarily of Southern and East Africa. *S. rotundifolius* is also cultivated in parts of Asia—notably India, Sri Lanka, Malaysia, and Indonesia. Its fellow species, as far as can be ascertained, is unknown as a crop beyond Africa's shores.

Despite their age-old heritage in cultivation and cuisines, both these crops are lacking in details and certainties. The literature treats them under a (sometimes inaccurate) mix of common names. The "northern" species (*S. rotundifolius*) is most often referred to as Hausa potato, Sudan potato, Zulu round potato, fabourama, and frafra potato. The "southern" species (*P. esculentus*) is most notably referred to as Livingstone potato, Madagascar potato, and scrambled eggs.

The literature also treats them under a (sometimes inaccurate) mix of scientific names. Taxonomists peering at the flowers and other parts have accorded these plants at least a dozen different scientific epithets.[4] Some of their claims may well be valid, and there may be hundreds of species of just *Plectranthus*, but for simplicity sake (considering that our audience is made up largely of non-botanists) this chapter presents the native potato resource as if there were just two species, which is most likely the case.

Smaller than the modern commercial potato, the tubers of *S. rotundifolius* are small and oval shaped, while those of *P. esculentus* are longer and thinner, extending from the bunch at the base of the plant like fingers. The tubers of both crops are mostly boiled, but they can also be roasted, baked, or fried. Indeed, they can probably replace potato in each and every recipe—even potato salad. The flavor, at least of *P. esculentus* as served in South Africa, is described as "quite a pleasant minty taste."

As far as industrial processing goes, little is known, because the quantities produced in any one location are generally small. However, given larger production, prepared food products seem quite possible. Flour milled from dried native potato (*S. rotundifolius*, there known as fabourama) is already produced in Burkina Faso, and it is reportedly turned into popular breakfast gruels. As of now, no one has reported on what sort of French fries or chips the tubers of this ancient crop yield.

Given their Mint-Family connection, it is no coincidence that the leaves of the plant are aromatic, but the tubers are neither fragrant nor flavorful. The tubers of *P. esculentus* have the kind of blandness that is preferred in a staple. The tubers of *S. rotundifolius* are much sweeter, by comparison.

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[4] These taxonomists include some of botany's biggest stars: John Gilbert Baker, George Bentham, Carl Ludwig von Blume, Nicholas Edward Brown, Auguste Jean Baptiste Chevalier, Julia Morton, Georges Samuel Perrottet, Jean Louis Marie Poiret, Anton Sprengel, and George Taylor. Among the species names they have proposed are *Plectranthus esculentus*, *P. rotundifolius*, *P. tuberosus*, *P. floribundus*, *Solenostemon rotundifolius*, *Coleus parviflorus*, *C. dazo*, *C. esculentus*, *C. tuberosus*, and *C. dysentericus* (hardly an inspiring name for a crop with a future).

Indeed, people are attracted to them for this very quality. Some liken the taste to sweet potato or parsnip. Probably in both species, however, the taste varies with locality and the individual clone of the plant. At least one observer notes that they are "an acquired taste, being rather bitter." In general, though, both tubers are well liked by both Africans and Europeans.

Currently, native potato is exclusively a smallholder crop. Indeed, it is almost exclusively a women's crop. Those who produce, collect, and process the tubers on their farms are female, both young and not so young. The tubers, overwhelmingly employed as subsistence food, make versatile family fare. They are good as a food-security insurance policy. They can, for example, be dried and put away for use during times of shortage. Although native potato is not a cash crop in the modern sense, part of the harvest is commonly put up for sale in the villages. Collectively, African women derive considerable income thereby.

Beyond the pocketbook issues, this crop is a reasonable contributor to dietary improvement. A standard serving provides a large percentage of the daily requirement of calcium and vitamin A (in the form of ß-carotene), as well as more than the daily complement of iron. The tubers contain 5-13 percent protein (calculated on a dry weight basis), or up to twice the amount found in potatoes (5 percent). In addition, the protein of *P. esculentus* is well endowed with essential amino acids (threonine, tyrosine, methionine, valine, leucine, lysine, etc.)[5] A serving thus contributes a fair portion of the daily protein requirement. The food-energy content is good as well—almost 400 calories per 100g dry matter in *S. rotundifolius* tuber.

Not only are the native potatoes nutritious, they are productive. Even in their current, horticulturally fairly primitive form, they can yield a lot of food from a small area. The recorded yields are 4 to 7 tons per hectare for *P. esculentus* and 15 tons per hectare for *S. rotundifolius*. And by employing the best plants and best cultivation practices under highly conducive conditions over 50 tons per hectare is supposedly obtainable, at least on experimental plots.

Despite these heartening signs of high production and good nutritional contributions, this is hardly a big resource in terms of geographical area or nutritional importance. Indeed, most Africans have never heard of it. Perhaps because the plants are basically hidden in plain sight no national or international research or extension organization has accorded it major support. This is unfortunate considering that calcium, vitamin A, iron, and protein—all of them vital to life—are typically deficient in rural diets in countries where this crop is found. And it is doubly unfortunate because these are big, bland staples that are eaten in bulk and can deliver quality nutrition in both a broad and a powerful manner across the society.

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[5] Allemann, J., 2002. Evaluation of *Plectranthus esculentus* N.E.Br. as a potential vegetable crop. PhD thesis, University of Pretoria, Pretoria, South Africa.

But without outside help a spontaneous adoption on a wide scale is unlikely. Working against these tuber crops is the popular impression that they are inferior, old-fashioned, outmoded foods. That impression resides in the minds of officialdom rather than of the village. It is primarily because of official (as opposed to consumer) neglect that the crop suffers from a lack of research support. And that lack is leading to sad consequences: In many locations this is another age-old resource that is dwindling toward obsolescence. And in Chad, where it is known as ngaboyo, it is said to be facing outright extinction.

Although much remains to be learned, native potatoes represent a pool of indigenous germplasm awaiting the specialists' plunge. They may never prove food-supply superstars, but they are well worth investigating. A recent report from the CGIAR declares that: "root crops will be many things to many people by 2020."[6] Driving the authors to this deduction is the root crops' adaptation to marginal environments, their vital role in promoting food security at the household level, and their flexibility in mixed farming systems. The authors note that root and tuber crops are often preferred over cereals both by farmers and consumers, and that they should be important components of programs, policies, and strategies aimed at improving the rural poor's welfare.

In this regard the native potatoes seem good candidates for pan-African attention. They are clonal crops that are easy to handle and propagate. They are found in the areas of low agricultural potential across the most needy regions of the continent. They occur where a shortage of suitable vegetable crops now results in endemic malnutrition. They produce large amounts of nutritious food from a small land area. And they seem primed for rapid advancement.

This last point may not at first be obvious. But because the native potatoes have not been subjected to intensive or extensive horticultural science, the immediate application of knowledge garnered from counterparts such as potatoes and yams—and even fellow mints—can likely bring a quick payoff. And in the long run native potatoes may have an even bigger payoff than anyone now could anticipate. Indeed, small agronomic improvements could well bring big jumps in yield. Also, more detailed research could solidify and enhance the nutritional and commercial gains to be reaped from the greater production.

Taken all round, then, these ancient native foods could prove good tools for reducing malnutrition and hunger, while improving farm profitability and providing African families with greater food security.

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[6] Scott, G.J., R. Best, M. Rosegrant, and M. Bokanga. 2000. *Roots and tubers in the global food system: A vision statement to the year 2020*. International Potato Center (CIP), Lima.

Tubers of native potatoes (here, *Plectranthus esculentus*) grow where a shortage of suitable vegetable crops now results in endemic malnutrition. They produce large amounts of nutritious food from a small land area. (James Allermann)

PROSPECTS

With these crops no one can foresee what the future holds for production or use. Not enough is known about the fundamentals to be sanguine about any future trajectory of supply and demand. The long term possibilities will become clear only as researchers burn away the mists of uncertainty and expose whatever potential is hiding behind today's doubt. But that could come quite quickly and here's what we think of the prospects for the different climatic zones.

Within Africa

Humid Areas Seemingly excellent. Tolerance to high temperature and rainfall is a feature of *S. rotundifolius*, which is widely (if thinly and irregularly) spread across Africa's tropical lowlands. *P. esculentus* prefers dryer conditions but is also in moist regions parts of South and East Africa.

Dry Areas Good but uncertain. In West Africa, to mention just one area, *S. rotundifolius* is grown from humid coastal areas to the dry interior woodlands. Nonetheless, during excessively dry periods irrigation will likely be essential to create an outcome that is commercially satisfying. *P. esculentus* produces reasonable yields in South Africa with annual rainfall as low as 450mm, although the rain must be well distributed through the season for the plants to produce under such parched conditions.

Upland Areas Uncertain, but possibly good. Native potato is generally regarded as a low-altitude crop, but some biologists have speculated that *S. rotundifolius* possibly evolved in Ethiopia. Likely, select types will be found that fit conveniently into upland habitat niches. In recent tests in South Africa *P. esculentus* has performed well at altitudes around 2000m.[7]

Beyond Africa

It is in Africa that the plants seemingly have their greatest potential, however *S. rotundifolius* is also grown in South and Southeast Asia, so there are opportunities for developing it there as well. There does not appear to be any reason why *P. esculentus* would not also be successful beyond Africa.

USES

Unlike the promising resources dealt with in other chapters, native potatoes are essentially one-product plants (omitting certain purported medicinal properties, that is).

Roots The tubers are mostly eaten as cooked vegetables. Like potatoes, they may be boiled, baked, or fried. However, one northern Nigerian type (a form of *S. rotundifolius* said to be distinguished by dark leaves) has tubers that can be eaten raw—something not even potato generally claims. The light colored tubers of *P. esculentus* in South Africa, Zimbabwe, and Zambia can also be eaten raw, and are reportedly eaten this way in Malawi too.

NUTRITION

The literature has so far provided few nutritional details from which to draw conclusions. One early report recorded a *S. rotundifolius* tuber sample as being 76 percent moisture. Its dry matter consisted of 91 percent carbohydrate, 5 percent crude protein, 4 percent fiber, 4 percent ash, and 1

[7] James Allemann writes: "The material that I am working with was collected in the Venda region of South Africa (altitude about 850m) and has given very good results at our research station (altitude 1,164m) and in community trial at an altitude of 1,500 to 1,700m."

percent fat. The nutritional energy was 392 calories per 100g.[8]

Recent studies on the nutritional value of *P. esculentus* in South Africa recorded (on a dry-weight basis): 81 percent carbohydrate, 13.5 percent crude protein, 4 percent ash, and 1 percent fat. In addition, the tuber material contained (in mg per 100g of plant material): vitamin A (0.2), thiamin (0.04), riboflavin (0.06), vitamin B-6 (0.3), phosphorus (337), potassium (1,721), calcium (140), magnesium (327), zinc (3.5), copper (1), manganese (1.4), sodium (73), and iron (50).[9]

HORTICULTURE

This perennial is normally grown as an annual. It is, as we've said, a smallholder crop, and is probably grown in as many intercropping patterns as there are farmers. None of the cultivation methods has been investigated, but many are likely to be interesting and to reflect long-tested local experience.

Propagation is by tubers, setts, stem-cuttings, or suckers sliced from sprouted tubers. However, the standard planting method is using tubers or portions of tubers. At the beginning of the wet season these are planted into mounds, ridges, or rows on prepared beds.

Obviously, the plants need to be spaced to fit the site, the climate, and the mix of species in the plot. However, the recommended spacing varies from 50 cm to 90 cm between rows and 15 cm to 30 cm between plants. The propagation materials should, it is said, be placed (horizontally where appropriate) at a depth of 5-8 cm.

In practice, fertilizer is rarely applied, but organic material incorporated liberally into the ridges or mounds before planting, followed by a shot of fertilizer once the crop has become established, are reportedly worth the effort and expense. As in potatoes, piling earth around the base of the plants as they grow encourages greater tuber development.

Even though caterpillars of various kinds feed on the leaves, pests are rarely of economic importance. With *S. rotundifolius* weeding is said to be required only in the first stage (before the spreading foliage shades out the competing species). However, *P. esculentus* plants do not spread to such a degree, and weeds remain a problem to the end of the season.

HARVESTING AND HANDLING

Depending on the place and the plant, the tubers are ready for harvesting after 120-200 days. In the case of *S. rotundifolius* all the aerial parts have by

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[8] This sample was from the West African type called "Hausa potato." Leung, W. 1968. *Food Composition Table for Use in Africa*. FAO. U.S. Department of Health, Education, and Welfare, Bethesda, Maryland.

[9] Allemann, op. cit. Figures are in grams per 100g plant material and are measured on a dry-weight basis.

then flowered and died back. *P. esculentus*, on the other hand, does not flower at the end of the summer growing season. Instead, it drops its leaves and goes into a dormant phase during the winter. With the warmth of spring, flowers pop out of the leafless stems, after which these stems die back and new fresh growth emerges from the tubers underground. For this reason, the plant is seldom seen to flower when cultivated.

There are literature claims that the mature tubers must be dug up promptly and protected carefully—that their skin is easily damaged and they deteriorate rapidly. However, recent research in South Africa indicates that the tubers of *P. esculentus* form wound tissue extremely fast, within a few hours, so post harvest diseases are not as bad a problem as expected.[10] *S. rotundifolius* tubers have a thicker skin and are even more resistant to damage. Nonetheless, post-harvest diseases and pests can be serious. Packing the tubers in dry sand and storing them in the shade has been found to extend shelf life.

LIMITATIONS

Although pests are not normally problematic, the tubers may harbor diseases, notably including viruses and bacteria. Other clonal tuber crops commonly carry a load of such afflictions, which are passed on generation to generation. The presence of such microbes has not been shown in Africa's native potatoes; however, the possibility that they are suppressing the crop at least in parts of Africa deserves consideration.

With such a neglected resource there may well be general marketing problems to resolve in each locality, even those that know it best. The possibilities for long-distance transport, for example, are limited by the tuber's short post-harvest life as well as a lack of processing methods and storage facilities.

NEXT STEPS

Sad to say, these indigenous resources are now among the most neglected of all edible plants. Few have begun to apply modern science and given them a chance to shine. Yet, as we've noted, native potato's development seems likely to help improve nutrition and income and reduce food crises at the household level. The most immediate actions should be those oriented toward small-farmer needs. But seen in broader context, programs covering the entire chain of production, from the plant's basic scientific underpinnings through to its production and utilization on a large scale, and even government policy, are needed.

Although the full extent of their adaptability has not been tested, the plants seem likely to prove useful in hunger-fighting interventions

[10] Information from James Allemann.

throughout much of the continent. They can grow in harsh climates to which conventional staples are poorly adapted. They appear to host few economically serious pests and diseases. And the foods they yield fit well into all or most traditional cuisines, including imported ones.

There is also a need to set up a native-potato rescue program. Its goals would be to publicize the species and its potentials, to advance fundamental knowledge of the crop, and to inspire consumers and companies to use more of it. In this regard, the fate of this food could depend on a dash of marketing savvy aimed at transforming its image as being somehow inferior. Women could take an active role in shaping these efforts. That would help to ensure that they achieve additional income instead of just additional work.

The following are offered as some possibilities for specific action.

Purify the Planting Stock As noted, many of the native potatoes that farmers now plant probably suffer from chronic afflictions of viruses and bacteria, which get passed on down the generations ad infinitum. The development of tissue-culture technology in recent decades provides a powerful tool for cleaning out such hitchhiking freeloaders. In the cases of other root and tuber crops this technology has produced almost miraculous leaps in plant health and productivity. Now a government research organization in South Africa has applied it to the native potato. The Biotechnology Division of ARC-Roodeplaat has developed a program of both meristem culture and thermotherapy that eliminates viruses from the tissues.[11] ARC-Roodeplaat is already providing virus-free planting material within South Africa.

This important advance could bring far-reaching and rapid improvements continent wide. Other African nations should take note. Through contracts, collaboration, or separate efforts, they could supply their own farmers with native potato planting materials uninhibited by chronic disease. In fact, a network of pure-stock providers covering sub-Saharan Africa could be the single advance that sparks a rapid renaissance in this very old and much neglected indigenous food plant.[12]

In addition to providing virus-free germplasm, ARC-Roodeplaat maintains an in-vitro genebank containing South Africa's selected and unselected materials. For other nations this too is worth copying or collaborating. Keeping tubers viable in long-term storage is difficult if not impossible; keeping the tissues in test tubes is easy by comparison.

Survey Part of the problem with these poorly documented crops is to know just what exists. It is therefore important to collect and evaluate the

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[11] Woodward, B.R., J. Allemann, and B.P. O'Regan. 1997. Tissue culture of cassava: A South African perspective. *African J. Root Tuber Crops* 2:243-245.

[12] In fact, several networks of enthusiasts, both in Africa and abroad, are forming; the power of the Internet should allow these groups to achieve a powerful synergy.

germplasm. Also, a search for the wild progenitors would go far toward establishing the crop's genetic identity and exact place(s) of origin within Africa.

To preserve this dwindling resource's genetic diversity for future generations should be a priority. Collections should be made especially in isolated areas. The agronomic traits of the different germplasm should be characterized and important qualities noted. Disease resistance and other standard qualities are of course important. But it is the tuber qualities that are paramount: size, shape, color, flesh texture, cooking qualities, and above all taste.

Women know most about how best to produce and process this crop and their knowledge should be also collected in the dozen or more countries that employ the crop most.

Taxonomy Someone (or preferably several persons independently) should gather representative tubers from different plant types found across Africa, grow them out, and conduct cross-pollination, DNA, and other identity tests. This will determine just how many species make up the crop that in this chapter we collect under the name native potato. Cross-pollination between the species (perhaps supported by modern techniques such as embryo rescue) might perhaps lead to more robust and bigger tubered varieties due to hybrid vigor and sexual sterility. Polyploid induction, which has been successful in enlarging ginger rhizomes, is also a possibility.

Physiology Here is a plant with a possible big future and almost no scientific past. It presents plant physiologists with a clean slate waiting to be filled in. Issues to resolve in the laboratory include:

- Daylength sensitivity;
- Processes of tuberization;
- Processes of pollination; both species seem to have major sterility problems, and reportedly do not produce seed.
- Rates of growth;
- Tolerances to soil type and soil nutrients;
- Limits of temperature and altitude; and
- Water requirements.

Propagation The whole issue of propagating these crops deserves investigation. In principal, the very best means of propagating the crop for small farmers would be via stem cuttings. Those little pieces of stem are easy to collect, easy to store and transport, and easy to put in the ground. In addition, they are available in huge quantity from parts of the plant that are not edible. Although it has been reported that stem cuttings root only reluctantly, recent research found that they root fairly easily under mistbed

conditions.[13] This discovery by itself makes the crop more attractive to prospective growers.

The standard method of propagating *P. esculentus* involves planting portions of the tubers, but the effect of planting small pieces of tuber on final yields has yet to be determined.

In the case of *S. rotundifolius*, the large and medium sized tubers are eaten, and the small ones used to establish the new crop. This is a process possibly leading to the preferential selection of plants producing small tubers, a feature also needing careful investigation.

Genetics In this clonal crop seed production is rarely considered or necessary, and the plant's genetics are barely known. They should now be investigated. Efficient plant-breeding strategies can likely be devised. They will not, however, be easy…given the sterility mentioned above. If crosspollination can be achieved, varietal improvement seems likely to produce rapid advances because plant breeders can select elite types out of open-pollinated populations and then clone them for farmers.

Targets for improvement include:

- Disease resistance;
- Large tuber size;
- Smooth and regular-shaped tubers;
- Fast (and perhaps slow) maturing plants;
- Photoperiod insensitivity.

Handling Clearly, there is a need for improved harvesting, cleaning, and processing. Techniques that lower labor requirements and/or enhance value are especially required. Methods that work on other root crops will provide invaluable guidance here.

Nutrition Nutritional studies would be more than helpful, especially those that can clarify the optimum dietary mix with other foods. A notable need is to evaluate the amino acids making up the protein.

In addition, there are odd and unconfirmed reports of the young shoots and leaves being used as boiled vegetables. The literature is unclear on how widespread and safe is this practice; some mints have toxins. The broad survey of the crop's users (mentioned above) will shed light on this, but there is a need to check the possible risk and possible reward of eating the young shoots as potherbs.

Food Technology Here again, virtually everything remains to be discovered. Food technologists could have a field day pioneering the better

[13] Allemann, op.cit.

handling and processing of an unexplored tuber with the potential to help needy people. In addition, consumption could be increased in urban areas as well as rural, providing that the tuber-based products are made available in convenient forms, both fresh and processed. Required are such things as:

- Extended storage life (temperature and humidity);
- Techniques to reliably transport tubers considerable distances;
- Processing and storage at the home and village levels; and
- Commercial processing (flour, chips, or fries for instance).

An interesting possibility is that the foliage might prove useful as a flavoring or fragrance. It is now a waste product, but the fact that it comes from a relative of basil, peppermint, and the rest suggests that it might have a future in many things from soups to soaps.

Horticultural Development The most fundamental field research involves developing an understanding of just how best to produce the crops in quantity. This includes:

- Mass production of quality planting materials;
- Cultural practices;
- Plant establishment;
- Optimum plant density;
- Production under shade;
- Production in poor soils;
- Cultivation under excessively wet conditions, and also excessively dry;
- Production systems that include legumes and rotations;
- Year-round production in the hot, humid tropics;
- Reproductive pruning (removing the flowers and tops of the plants to force bigger tubers); and
- Minimum fertilizer requirements.

Intercontinental Collaboration As mentioned earlier, it is noteworthy that *S. rotundifolius* is also grown in South and Southeast Asia. Possibly, Asia's great expertise on vegetable crops might be harnessed to provide Africa with new and developed germplasm as well as new insights into handling the crop. The reverse is also possible: African specialists can provide Asia with valuable germplasm and insights of their own. Also, it may be possible to obtain expertise in tuber-crop development from South America (notably at the International Potato Center), as well as properly introducing an African tuber crop to the lands across the Atlantic.

SPECIES INFORMATION

Main Botanical Names *Plectranthus esculentus* N.E. Br. and *Solenostemon rotundifolius* (Poir.) J.K. Morton

Synonyms *Coleus esculentus*, *Coleus dazo*, *Coleus dysentericus*, *Coleus parviflorus*, *Coleus tuberosus*, *Plectranthus rotundifolius*, *Plectranthus tuberosus*, *Plectranthus floribundus* among others

Family Labiatae (Lamiaceae) Mint Family

Common Names

Afrikaans: Wilde aartappel
Burkina Faso: fabourama
Mali: fabourama
English: Livingstone potato, wild potato, country potato, Hausa potato, Madagascar potato, coleus potato, Sudan potato, scrambled eggs, Zulu round potato (*S. rotundifolius*), elongated native potato, Swedish begonia
French: Madagascar potato
Ghana: fra-fra potato
Nigeria: saluga, tumuku, Rizga (Hausa)
Chad: ngaboyo
Tswana: umbondive(ck)
Venda: Mutada, Matheta
Zulu: Umbondive, Ibonda, Ugilo, Ulucanqu, Uluhlaza, Isisqwili, Ushizane, Umhlati, ulujilo, Imbondwe, uJwangu, uShizan, uJilo, uJikwe, uHlazaluti, iZambhane
Sudan: Fa-Birama
India: koorka, koorkan, kizhangu
Indonesia: *ketang, kentang dwaja*
Malaysia: kembili, ubi kembili
Sri Lanka: innala, ratala
Malawi: buye, nyumbu, njowe, cezani
Siswati: Mlata
Shona: Shezha, Tsenga, Tensa, Tsenza
Tswana: Makwele e Sechuana
Sotho: Tapole emahlo (wild), Tapole-ea-mahlo
Xhosa: Itapile

Description

The plants are perennial herbs with prostrate or ascending habits. *Plectranthus esculentus* grows about 1 m high; *Solenostemon rotundifolius* is more prostrate and is generally under 30 cm tall. Each has a distinctive fragrant or pungent odor, due to volatile oils contained in glands or sacs in the leaves and other parts.

The stem, which is succulent and square in cross-section, is covered in white hair. The prostrate, lateral, trailing branches root at the nodes.

The leaves form in opposite pairs or whorls at intervals along the stems. They are hairy, oval, and aromatic. They can be up to 6 cm long and have toothed margins. Some plants have a central purple marking on the lamina.

S. rotundifolius flowers before the stems leaf out. In *P. esculentus* flowers are found in early spring on leafless stems. In both species they are borne on elongated, terminal racemes. Each flower is small (about 1.5 cm long) and bilaterally symmetrical with united petals, and a four-lobed ovary that produces four one-seeded nutlets. In color, they are variously reported as being violet, deep red, or yellow. Seed-set seems rare, and pollinators are unknown (though bees probably pollinated their ancestors).

The shallow, fibrous root system produces tubers that are dark brown or black in color and form in clusters around the base of the stem. Those from *S. rotundifolius* are round to ovoid and generally egglike. Those from *P. esculentus* are roughly cylindrical, up to 2 cm in diameter and 5 to 10 cm long (some as long as 25 cm have been found in south Africa).

Distribution

Possibly of Ethiopian or, more likely, later multiple origins, these and related species are now widely distributed in Africa.

Within Africa Cultivated in West, Central and southern Africa. Also reported in East Africa.

Beyond Africa South and Southeast Asia (India, Sri Lanka, Malaysia, Indonesia).

Horticultural Varieties

Basically, there are no formal varieties. However, the West African agricultural literature refers to:

- variety nigra, with small tubers and black skin, widely grown in Mali and the Upper Niger region;
- variety robra, small, red-gray or red-yellow tubers; and
- variety alba, a white-tuber variety which is also cultivated in the Upper Niger region.

Environmental Requirements

Like most else about this crop, the environmental requirements are uncertain.

Rainfall For *P. esculentus*, acceptable yields have (as already noted) been obtained with as little as 450mm. For *S. rotundifolius*, however, the minimum annual rainfall requirement is said to be approximately 1,000 mm. The plant is clearly adapted to relatively high rainfall, but it produces optimum yields only in areas where the precipitation is distributed throughout the growing period.

Altitude Limits are unreported.

Low Temperature A freeze is likely to be fatal to both crops, but in trial plots in South Africa *P. esculentus* has survived short periods of -3°C and *S. rotundifolius* -5°C.[14]

High Temperature Unknown. Temperature tolerance is a feature of many root and tuber crops although very high soil temperatures are generally damaging.

Soil Like most root crops, this one responds best in deep, well-drained sites that are well prepared before planting so that the underground portion can swell to its full size with minimal restriction. Well-drained sandy loams are preferable to clays since the crop is sensitive to waterlogging.

Daylength Sensitivity Recent work shows the South African variety is daylength sensitive with a critical photoperiod of 12.5-13 hours.[15]

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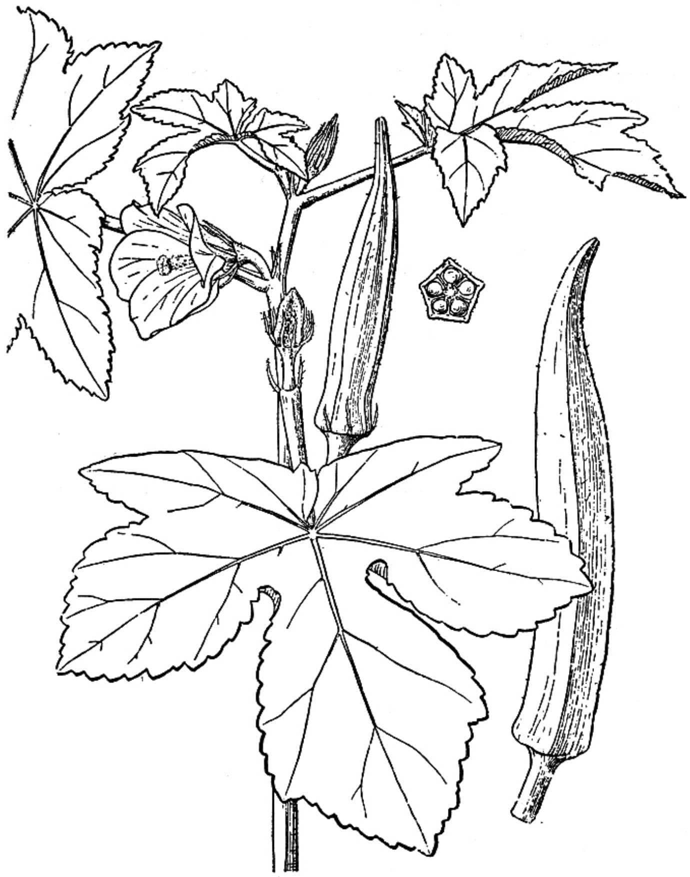
[14] Allemann, ibid.
[15] Allemann, ibid.

Related Species

Several southern African wild *Plectranthus* species are also edible, with one at least regarded as a delicacy in the winter season. These extremely obscure roots have never been domesticated and probably don't warrant a formal attempt. Nonetheless, in the context of native potato research, they could perhaps provide valuable insight into such things as genetic and physiological effects.



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OKRA

Given the fact that it already grows almost everywhere in the tropical, subtropical, and warm temperate regions, okra would seem misplaced in a book on lost crops. Furthermore, only in a few locations has it developed into a major resource. Although perhaps a hundred nations know this African species first hand, none has raised it to anything like the heights attained by, say, cabbage, carrot, or common bean in the western world. For this there seems good reason: People generally don't take to okra. In a 1974 survey made by the United States Department of Agriculture, for instance, adults named okra as one of the three vegetables they liked least, and children rated it with the four they liked second-least.[1]

The sticky, mucilaginous juice inside the pods is the main objection. That slime blinds everyone to the plant's greater potential. Of course, there are places where okra is regarded with something akin to reverence. Neither New Orleans nor West Africa, for instance, would be the same without it. But, given the crop's overall status, most observers would logically conclude that okra's natural limit as a global resource was reached long ago.

Seen in even broader perspective, however, that would be a suspect conclusion. In reality okra could have a future that will make people puzzle over why earlier generations failed to seize the opportunity before their eyes. In the Botanical Kingdom it may actually be a Cinderella, though still living on the hearth of neglect amid the ashes of scorn. Following are some reasons why it could soon rise and take a place alongside the royalty of crop plants.

This plant is perfect as a villager's crop. For one thing it is easy to grow, robust, and little affected by pests and diseases. Also, it adapts to difficult conditions and can grow well where other food plants prove unreliable. For another, it provides good yields and possibly more products than any other vegetable. For a third, it is full of nutrients. And, economically speaking, its products are within almost everyone's reach.

[1] At least in the United States it is seldom cooked as a separate vegetable for its own sake, although there are exceptions—an okra and tomato dish in Texas, for instance, or Charleston's Limping Susan, a blend of rice and okra.

USDA Farmers Market, Washington, DC. Okra is an African market vegetable now found in cuisines as disparate as French and Japanese. It is common throughout South Asia and, of course, it is popular in Caribbean and African cooking. The word gumbo derives from a Bantu word—ki ngombo—for this vegetable. The size of a thick, long green bean, this vegetable is high in fiber and provides solid provitamin A and vitamin C, as well as minerals such as calcium, magnesium, and potassium. Okra can be boiled, blanched, fried, sauteed, and steamed and is even tasty when raw, young, and fresh. So why don't we see more of it in supermarkets and on restaurant menus? (M.R. Dafforn)

For a food resource, the okra plant is strange; it is a coarse, upright herb bearing fuzzy green pods somewhat reminiscent of beans. Their mucilage may turn off newcomers, but many Africans, and a growing number of others, consider the slithery texture no deterrent—indeed, they see it as perhaps okra's most desirable feature. A popular soup vegetable, very much appreciated in West Africa for its thickening power, okra pod is used both fresh and dried.[2] Dry pods are also pounded into flour that is commonly added to foods. In the Sahel, this flour is also used in the final stages of preparing couscous, as it prevents the granules sticking to each other.

In America, where it appears almost exclusively in stews and soups, okra is usually seen in cross section, cut into disks that look like little cartwheels with a seed nestled between each pair of spokes. Okra is also the key ingredient in gumbo, the famous dish of the American South.

[2] One study, for example, found that fresh or dried okra was the vegetable most frequently used in the Baoulé of central Côte d'Ivoire.

The plant is primarily employed, of course, as a vegetable; its pods, seeds, leaves, and shoots, as well as the outer cover of the flowers (calyx) are all eaten as boiled greens. But that is just the beginning. Okra seeds contain protein as well as oil possessing qualities like those of olive oil, the standard of excellence. And the seeds produce their protein and oil in goodly quantities. One experiment in Puerto Rico documented yields of 612 kg per hectare oil and 658 kg per hectare protein.[3] Such quantities rival those of other oil-and-protein crops of both temperate and tropical zones.

Like soybean, the seed provides excellent vegetable protein for uses including full- and fat-free meals, flours, protein concentrates and isolates, cooking oils, lecithin, and nutraceuticals (foods with functional health benefits). Okra protein is both rich in tryptophan and adequate in the sulfur-containing amino acids, a rare combination that should give it exceptional power to reduce human malnutrition. In addition, byproducts such as hulls and fiber can be used for animal feeds.

Even the "slime" might be marketable. The plant could have a future in serving the booming markets for health foods. Given an aging global population increasingly concerned over sickness prevention, mucilage is big business these days. Gums and pectins of a type comprising nearly half of each okra pod are thought to help lower serum cholesterol in the bloodstream.[4] Okra is also widely recommended as one dietary tool to help stabilize blood sugar in diabetics, because its high soluble fiber may cut the pace at which sugars are absorbed from the intestine.

The plant could have a future also as a supplier of commercial laxative ingredients. Its gelatinous substances absorb water, swell, and ensure the bulky stools that obviate and overcome constipation. Any and all dietary fiber is helpful but okra seems to rank with two crops now commanding multimillion-dollar markets: flaxseed and psyllium.[5] In other words, this vegetable may not only bind excess cholesterol and toxins but assure their quick and easy passage out of the body.

The okra plant could also provide the world with mucilage for topical use. A similar polysaccharide gum comes from aloe vera, a traditional plant exploding in use because its products are believed to help heal wounds, soothe burns, minimize frostbite damage, and perhaps provide other medicinal benefits. Despite a lack of detailed evidence, there seems no reason why okra mucilage cannot play a part in supplying industries that

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[3] Mangual-Crespo G. and F.W. Martin. 1980. Effect of spacing on seed, protein, and oil production of four okra varieties. *J Agric Univ Puerto Rico* 45:450-459.

[4] Jenkins, D.J.A., C.W.C. Kendall, A. Marchie, D.A. Faulkner, J.M.W. Wong, R. de Souza, A. Emam, T.L. Parker, E. Vidgen, E.A. Trautwein, K.G. Lapsley, R.G. Josse, L.A. Leiter, W. Singer, and P.W. Connelly. 2005. Direct comparison of a dietary portfolio of cholesterol-lowering foods with a statin in hypercholesterolemic participants. *Am J Clin Nutrition* 81(2):380-387.

[5] The ingredient in such well-known American products as Metamucil®.

now employ aloe vera. Already it is the hidden ingredient that makes catsup so hard to get out of the bottle. Okra gum is also potentially useful as an extender of serum albumin and egg whites. It has even been used to size paper in Malaysia.

This versatile plant could also have a future producing top-of-the-line paper of the sort used to make fine documents and currency. In this case, the fibers on the outside of the stalk are used. Okra has "bast fiber" like that of its close cousin kenaf (*Hibiscus cannabinus*). Both these fast-growing, look-alike African cousins open the possibility of farmers joining foresters to fill the world's insatiable demand for paper. In the United States, kenaf has already created a small industry. Kenaf is said to produce annually more paper per hectare than southern pine, the country's most productive papermaking tree. And it is harvested every five months, rather than every 30 years, which eases market planning and makes for many other efficiencies. Moreover, kenaf paper is stronger, whiter, longer lasting, more resistant to yellowing, and has better ink adherence than pine-tree paper. Although it apparently hasn't been tested yet, okra paper seems likely to be just as good.

Beyond all that, this plant could have a future also as a producer of various products used to soak up liquids. These special materials are made from the pith that remains after the stem fiber has been stripped away. In kenaf, this byproduct is proving suitable for animal bedding, for sopping up oil spills, for chicken and kitty litter, and for potting soil. It seems likely that okra's counterparts would be comparable.

Based on the rising experiences with its country cousin, okra could, at least in principle, have a future producing yet more things that are strange for a vegetable crop, including:

- Construction materials. (Kenaf-blend panels are said to perform better than the present particleboard.)
- Handicrafts. (Kenaf fiber makes excellent mats, hats, baskets, and more.)
- Forage. (Chopping up the whole kenaf plant and feeding it to animals has proven successful.)
- Fuel. (Kenaf roots and stems of burn fiercely.)

In sum, this African resource could be a tool for improving nutrition, rural life, rural development, foreign exchange, and much more.

PROSPECTS

Seen in light of the above information, okra might have a grand future as an industrial crop. And there seems to be little difficulty in producing the

Berekum market, Dormaa District, Brong Ahafo Region, Ghana. A perfect villager's vegetable, okra is robust, productive, fast growing, seldom felled by pests and diseases, and high yielding. It adapts to difficult conditions and can thrive where other food plants prove unreliable. Among its useful food products are pods, leaves, and seeds. Among its useful non-food products are mucilage, industrial fiber, and medicinals. Seen in overall perspective, this often-derided resource could be a tool for improving many facets of rural life. (Nigel Poole)

plant on a large scale. In the United States, for example, some is already produced in quantities big enough for the pods to be canned, frozen, or brined for the nation's supermarkets. As a fresh vegetable the crop's prospects are more enigmatic, but positive for all that. As with avocado or whisky, the palate's initial resistance usually mellows with greater exposure. But at core, it is an African vegetable whose greatest beneficence may well lie with its people.

Within Africa

Humid Areas Excellent. Fast-maturing types are well suited to tropical heat and humidity.

Dry Areas Excellent. Although not structurally adapted to growing under desert conditions, the plant shows remarkable tolerance to drought and heat and can generally perform reliably in Africa's savanna regions.

Upland Areas Excellent. With a crop as adaptable as this, there should be no trouble finding varieties to fit into localities up to about 1,000 m in elevation that have a reasonable growing season.

Beyond Africa

Okra is clearly not restricted to Africa. Indeed, it performs exceptionally well elsewhere. In South Asia as well as in tropical America, China, and perhaps Australia and the United States, it might well become a new agroindustrial resource.

USES

Everything part of this plant seems to offer some useful purpose or other.

Pods In their immature form the pods are the plant's main edible portion. Although mainly employed as a boiled vegetable, they can be stir-fried, battered and deep-fat fried, microwaved, steamed, baked, and grilled. Some are blanched and processed as a frozen (plain or breaded), pickled, or canned product.

Whether boiled, added to soups, or sliced and fried, the pods have a unique flavor and texture. They may be used alone or mixed with other vegetables. Mucilage released when okra slices are fried is known to be a good thickening agent for gravy. In West Africa, young pods are thinly sliced to prepare okra soup, which has been called "a perfect partner with fufu" (the region's main staple, made of starchy roots).

Inside the dried pods the gums stay intact and remain useful for flavoring and thickening foods. West Africans slice, sun dry, and grind pods into a powder that is put away for the hungry time that hits each year just before the new harvest. In Turkey the pods are strung out to dry for winter use.

Seeds Typically, the seeds are obtained from pods that become too mature to be eaten fresh. The cooked pods can also be squeezed to expel the seeds. Those seeds are commonly used in place of dried peas or beans or lentils in soups or in other dishes, including rice.

Coffee Substitute Mature dried seeds can be roasted and ground as a coffee substitute. This was once widely used in places like El Salvador and other Central American nations, Africa, and Malaysia. According to one report "the resulting 'coffee' has a good aroma and is inoffensive, since it lacks the stimulating effect of caffeine." A prominent book on African wild foods calls okra "one of the best coffee substitutes known."

Oil and Protein Okra seed's potential as a source of oil and protein has been known since at least 1920. About 40 percent of the seed kernel is oil.

This greenish-yellow liquid has a pleasant odor and a high (70 percent) content of unsaturated fatty acids, especially linoleic and oleic. It has a short shelf life but is readily hydrogenated and could be used to make margarine or shortening.

The residue left after oil extraction is a possible feedstuff. It contains over 40 percent protein as well as relatively high amounts of thiamin, niacin, and tocopherol. But some lingering questions of possible toxicity remain to be answered (see later).

Curd A research team in Puerto Rico has surprisingly found that okra can be turned into "tofu."[6] Led by Franklin Martin, the experimenters ground the seeds finely in water, strained the aqueous mixture through a cloth filter, and precipitated the protein by adding bivalent salts (such as magnesium sulfate) or acid (vinegar or lime juice). A taste panel found okra-tofu pleasant to eat fresh or cooked or as a cheese substitute. The protein and oil contents were as high as 43 and 53 percent, respectively.[7]

Leaves In areas where a wide variety of leaves are eaten (notably West Africa and Southeast Asia) tender okra leaves are often part of the daily diet. They are most frequently cooked like spinach or added to soups and stews. Some okra varieties have hairy leaves, an objectionable feature reduced by cooking; others are hairless. In West Africa the tender shoots, flower buds, and calyces are traditionally thrown into the pot as well. As with the pods, okra leaves are frequently dried in the sun, crushed, or ground to a powder, and stored for future use. In taste, they are somewhat acidic. By carefully picking lower parts of the plant it is possible to get a good crop of leaves without reducing the number of seedpods further up the stem.

Biomass At the end of the harvest season, the remaining foliage and stems can weigh 27 tons per hectare. This is quite burnable. The stems generate considerable heat but no sparks, excessive smoke, or bad smell. On the other hand, these light stems burn only briefly and to be useful may need a special stove. With fuel costs rising worldwide and new technologies promising efficient conversion to liquid fuels, okra biomass seems likely to become notably useful, especially as more tropical forests are destroyed.

Mucilage Obtaining the mucilage is simple. Slices of the immature pod are merely placed in water. Boiling thickens the mix. The mucilage is actually an acidic polysaccharide composed of galacturonic acid, rhamnose, and glucose. It achieves maximum viscosity at neutral pH, and tends to break down when overheated.

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[6] Martin, F.W. and R.M. Ruberte. 1979. *Edible Leaves of the Tropics*. Antillan College Press, Mayaguez. (3rd Edition, 1998, available via ECHONet.org.)
[7] The percentages were measured on a dry-weight basis.

Ornamental Okra is closely related to the common ornamentals known as flowering hibiscus, making okra's large and attractive blossoms seem somehow familiar (although they are yellow and sometimes come with a crimson center). The pods also have an interesting shape, and those that become too hard to eat can be dried, cured, and felicitously slipped into everlasting flower arrangements.

Medicinal Use People in the East have long used the leaves and immature fruit in poultices to relieve pain.

NUTRITION

Okra is more a diet food than staple. Pods are low in calories (scarcely 20 per 100 g cooked), practically no fat, and high in fiber. It does provide several valuable nutrients, including about 30 percent of recommended levels of vitamin C (16-20 mg), 10-20 percent folate (46-88 µg), and a little more than 5 percent vitamin A (14-20 RAE).

The leaves provide protein, calcium, iron, and vitamins A and C. No toxic substances have been reported in the leaves.

As noted earlier, the seeds are potentially a good source of an especially nutritious protein. In screening a large collection of seeds in Puerto Rico, it was found that their protein contents varied from 18-27 percent.[8] The protein's amino-acid profile differed from that of either legumes or cereal grains.[9] It was rich in tryptophan (94 mg/g N) and had an adequate content of sulfur-containing amino acids (189 mg/g N). This okra protein thus complements, balances, and fulfills that of cereal grains and legumes, not to mention root crops. One advantage to processing okra seed is its simplicity. A hand mill and sieves were all it took to separate a high protein (33 percent), high oil (32 percent) meal from the hull.[10]

HORTICULTURE

Today, almost all okra is interplanted with other crops in small farms, in backyard gardens, and sometimes in truck farms established on the fringes of cities. Only in a few places is it grown alone on large commercial fields. Most is direct seeded. Owing to the thick seedcoat, the seed is first soaked overnight to improve germination. Seedlings can also be transplanted from a

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[8] Information from F. Martin, based on Karakoltsidis, P.A. and S.M. Constantinides. 1975. Okra seeds: A new protein source. *J Agric. Food Chem* 23:1204–1207

[9] The limiting amino acids were valine, isoleucine, and lysine or threonine. P.A. Savello, F.W. Martin, and J.M. Hill. 1980. Nutritional composition of okra seed meal. *J Agric Food Chem.* 28(6):1163-6.; J.P. Cherry, personal communication.

[10] Martin and Ruberté, op.cit. These researchers also showed the usefulness of this meal in baked products.

nursery. Warm temperatures are needed both for good germination and good growth. Okra is similar to cotton in its temperature requirements. Commercial okra in the United States is planted at a population of 20,000-30,000 plants per hectare.

The crop is relatively free from pests and requires only minimal maintenance. However, in the southern United States, it can be subject to *Verticillium* and *Fusarium* wilts, and aphids, corn earworm, and stinkbugs can be major insect pests.

HARVESTING AND HANDLING

Flowering begins about 2 months after planting. Each flower then develops rapidly into a pod, which is typically harvested just 3-6 days after the flower formed. Pods harvested at this stage are tender, flavorful, and about half grown. Any that remain on the plant quickly turn fibrous and tough.

With proper field management, continuous flowering and high production can be maintained. Yields approaching 500 kg per picking per hectare (0.5 kg per plant) may be produced during a harvest period of 30-40 days. Okra is usually harvested at least three times a week. The pods have a high respiration rate and should be cooled quickly. Those in good condition will keep satisfactorily for 7 to 10 days at 7 to 10°C. A relative humidity of 90 to 95 percent helps prevent shriveling.

LIMITATIONS

The most important step in any vegetable-okra operation is harvesting the pods correctly and regularly picking the pods every few days. That induces more production and greatly increases yield.

Fresh okra pods bruise easily, blackening within a few hours. A bleaching type of injury may also develop when they are held for more than 24 hours without cooling.

Some okra plants and pods have small spines to which some people are allergic. Picking the crop can produce itchy arms.

NEXT STEPS

Of all the earth's useful plants this is one of the most misunderstood. Taken all round, it likely offers as many production possibilities as ever dreamed in a single plant. However, it also is stuck in a mental warp. Although it holds enough potential to keep a dozen researchers productive for their lifetimes, few are seriously developing it at present.

Industrial Development

With such an array of possibilities, several rural industries might be built around this species, much as around bamboo or rattan in eastern Asia. Okra

thus offers a possible route to prosperity for both small-scale and large-scale producers in numerous nations. Here are some options.

Oilseed No one knows the future okra could have as an oilseed, but at least at first sight it could be quite big. The oil is easily extracted using either solvent or mechanical press. Both the greenish-yellow color and the not unpleasant odor are easily removed. Machinery for harvesting the seed has been developed and to extract the oil machinery designed for cottonseed can be employed.

Needed now is a major follow-up to the work in Puerto Rico, which has been overlooked since it was published decades ago.[11] This should start with test plantings large enough to yield samples of okra seed oil and protein for modern evaluation by chemists, food technologists, and industries that purchase vegetable oils and proteins. It's a big undertaking, considering that okra oil and okra seed protein have never been produced in quantity before, but it could open the door to a new agroindustry for the warmer regions of the world.

Mucilage On the surface, there seems no reason why okra mucilage cannot play a part in supplying industries that now employ psyllium, flaxseed, and aloe vera. However, confirmation is needed. Issues needing clarification include the performance of okra product, safety, and likely price range. Again, growers or researchers should produce enough for evaluation by chemists, food technologists, and companies that buy mucilaginous materials. Again, it could open up the possibilities to vast new industries for many lands.

Paper Pulp Any reader who already grows okra may by now be wondering if we really know the plant. But that is only because the types grown for vegetable purposes are specially bred dwarfs, typically less than a meter in height and surely inappropriate for papermaking or fuel or particleboard. However, among this species' huge biodiversity are African varieties with stems towering 5 m and "trunks" like small trees (up to 10 cm diameter). At least in principle, those can be harvested for pods, seeds, and leaves and later felled for fiber or fuel. Some varieties even show a perennial nature. This multi-year production—like the ratooning used with sugarcane—saves the expense, trouble, and delay that comes with making a second planting.[12]

In the temperate-zone summer most of these tall, robust, West African okras bloom too late to set seed. Instead, they devote their considerable energy to vegetative growth. Far surpassing garden varieties in the

[11] Martin and Ruberté, op.cit.

[12] As far back as 1979, J. L. Siemonsma described two distinct types of okra from Côte d'Ivoire, and brought the existence of almost perennial races to attention.

production of fiber and biomass, they have the potential to revitalize okra breeding and okra as a global resource.

These tall types should be obtained and put into worldwide trials. Some trials should involve side-by-side comparisons with kenaf.

Bioabsorbents Pith, as we've said, comprises a major part of the stem. In kenaf it is proving suitable for animal bedding, oil-absorbents, chicken litter, kitty litter, and potting soil. Okra pith samples should be gathered and compared with kenaf's. For these purposes, the two crops are less in competition than in cohoots. They can undoubtedly be marketed together and perhaps even mixed, thereby building a bigger, broader, and safer base of supply. Demand for bioabsorbents like these is likely to soar, both for the needs of environmental health and public health around the globe.

Horticultural Development Although there has been considerable selection and breeding of okra, it has emphasized the production of immature pods. The rest of the fantastic genetic diversity within this species is basically untapped, or even unexplored. That situation should be changed, and fast. Germplasm needs to be gathered up not only in Africa but also in Asia and other regions that know the crop.

With this genetic variability in hand, the way should be open for improving the compositional value of the crop for the various separate products. Varieties could be bred, for instance, for fiber, biomass, oil, protein, mucilage (type and yield), color, and ornamental use. Breeding studies could also be expanded to include improving yields, cultivation conditions, nutritional value, and nutraceuticals.

Okra flowers are structured for insect-pollination (bees, wasps, flies, and beetles, and perhaps even occasional birds), but self-pollination usually occurs and both hand-pollination and seed handling are straightforward. Controlled breeding is thus not difficult, although success in bringing out some characteristics may require very large populations and very careful evaluation.

Toxicity Checks Although both okra tofu and the protein-rich residue left after oil extraction offer promising foods and feeds, there is a possible drawback. Okra seeds, like cottonseeds, purportedly contain gossypol or a gossypol-like compound.[13] All doubts will have to be removed before okraseed can be employed as a protein source. Strangely, should gossypol be present in commercial amounts it might possibly be used for the long-sought male contraceptive (see sidebar).

In at least some okraseed varieties the oil contains small quantities of cyclopropenoid fatty acids. These unstable compounds have strong

[13] Gossypol occurs also in cottonseed oil, from which it is extracted with butanol.

physiological effects and in hens are believed to suppress egg laying. However, the fact that some okra plants had only low quantities (the overall range was 0.26-5.59 percent) suggests that the problem might be bred out. These unusual fatty acids are easily removed by heating the oil during processing, but having none to start with would surely be better.

Basic Studies There are undoubtedly many fascinating physiologic and genetic features of the plant to investigate. Here are three that come to mind:

- *Ploidy* Okra has a high number of chromosomes (2n=130) and behaves in some instances as a diploid and in others as a tetraploid. It is thought that one genome possibly comes from *Abelmoschus tuberculatus* (2n=58). Modern techniques could likely go far in sorting out okra's genetic background and chromosome make up.
- *Hybridization* Crossings within the species as well as possible hybrids with okra's close, interesting, and useful relatives ambrette (*Abelmoschus moschatus*), kenaf, and roselle (*Hibiscus sabdariffa*) could provide fascinating plants with exceptional properties.
- *Okra's origin* Many publications still give the species' origin as India, but that seems more current usage than scientific assessment. The vast occurrence of primitive types and wild relatives in Africa (especially Ethiopia) indicates okra is almost certainly African, but the lingering doubt should be put to rest by groundwork and DNA testing.

Food Technology

Here, too, are possibilities for fascinating research. Examples include:

- *Okra Tea* Okra's close cousin roselle has been making a name for itself in recent years as a major ingredient in non-caffeinated teas (notably in the United States, where it stars in the popular Red Zinger Tea®). Jamaicans know this okra relative as sorrel and consider it one of the island's great delicacies, turning it not only into cooling beverages but into famous tarts and jellies as well. It is also a common tea in the Sahel, where it was introduced to provide plant fiber and vitamin C, and has now naturalized. Okras with red calyxes are known and should be tested for the possibility of producing a counterpart.
- *Decaffeinated Coffee* Could okra seed be a direct route to a really good caffeine-free beverage? That is something for which a market seems more promising now than ever before, and the possibility deserves at least a look-see.
- *Gum-Free Okra* Needed also is a simple test for mucilage content that would allow the germplasm to be screened. Then, pods of known polysaccharide content could be bred. Anyone creating gum-free okra will have given the world a major new crop. Of course, anyone creating

exceptionally gum-rich okra will also give the world a major new crop.

Progress and Public Relations In spite of the fact that okra is a potentially very important plant, little effort is being given to its development. As noted, this is largely due to the public's negative mindset. To overcome popular repugnance requires more than science…it requires publicity. Some sort of Okra Appreciation Society would help give the vegetable a good push. It might foster newspaper and magazine coverage of okra's possibilities. And it might operate such things as contests, recipes, home-economics courses, and nutritional awareness demonstrations. Although the plant's prospects are high, its future depends on a mental course change to break it out of the slime still blinding everyone to the crop's greater potential.

SPECIES INFORMATION

Botanical Name *Abelmoschus esculentus* (L.) Moench

Synonym *Hibiscus esculentus* L.

Family Malvaceae

Common Names

Arabic: bamia, bamya, bamieh
English: okro, lady's finger, ladies finger, gumbo
India: bhindi, bindi, dheras, bandakai, vendakai
Chinese: ka fei huang kui, huang su kui, huang qiu kui, qiu kui (medicinal name); chan qie, ch'aan k'e, Ts'au kw'ai (Cantonese)
French: gombo, bamie-okra, ketmie comestible, ambrette
German: ocker
Spanish: gombo, ají turco, quimbombo, ocra
Portuguese: gumbro, quingombo, quiabo, quillobo
Akan (Twi): nkruman, nkruma (okra)
Bantu: ki ngombo, ngumbo, gombo
Congo, Angola: quillobo, ki ngombo
Swahili: gumbo
Thai: krachiap khieo, krachiap mon, bakhua mun
Greek: bamia
Hebrew: bamiya, hibiscus ne'echal
Hungarian: gombó, bámia
Italian: gombo, ocra, bammia d'egitto, corna di greci
Japanese: okura, Amerika neri, kiku kimo
Malaysia: bendi, kacang bendi, kacang lender, sayur bendi , kacang lendir , kachang bendi
Indonesia: kopi arab.

Description

Okra is an annual herb typically reaching 2 m in height, but some African varieties may grow up to 5 m tall, with a base stem of 10 cm in diameter.

The heart-shaped, lobed leaves have long stems and are attached to the thick woody stem. They may reach 30 cm in length and are generally hairy. Flowers are borne singly in the leaf axils and are usually yellow with a dark red or purple base. Some African varieties are photoperiod sensitive and bloom only in the late fall in temperate zones. It is largely to wholly self-pollinated, though some out-crossing is reported and it is often visited by bees.

The pod (capsule, or fruit) is 10-25 centimeters long (shorter in the dwarf varieties). Generally, it is ribbed or round, and varying in color from yellow to red to green. It is pointed at the apex, hairy at the base, and tapered toward the tip. It contains numerous oval seeds that are about the size of peppercorns, white when immature and dark green to gray-black when mature.

Distribution

The plant is immensely adaptable and is widely distributed in the tropics, subtropics, and warmer temperate zones. In essence, it grows almost everywhere anyone tries to plant it.

Within Africa Of all the native food crops, this is one of the most widespread within the continent. It is known from Mauritania to Mauritius, with most diversity centered around Ethiopia and the Sudan.

Beyond Africa It is now grown throughout southern Europe, Australasia, tropical Asia and America, the Caribbean, and the United States, where it is best known in the southern region but is also cultivated in Oregon and California. Turkey grows okra on a large scale.

Horticultural Varieties

Many cultivars have been selected for local conditions but in the main there are two types: the long and the short (quickly flowering) duration. The cultivars vary in plant height and in shape and color of the pod. With all the different cultivars and their variations, the particular kind of okra planted usually reflects what the local people prefer their dinner dishes to look like.

Although okra prefers a long, hot growing season, cultivars have been developed that are short in stature as well as fast maturing, and small fruited. These dwarf, short-duration types reach a height of 60 cm and require only 7 to 9 weeks to mature.

The okra seen in the temperate zones is fairly uniform. One survey of

266 temperate-zone varieties found no consistent differences. But that is misleading; this species encompasses huge genetic diversity that not even okra specialists have ever seen—it just hasn't been distributed in the temperate zones.

Environmental Requirements

Okra is a warm-season annual well-adapted to many soils and climates.

Rainfall The plant tolerates a wide variation in rainfall.

Altitude Most selections are adapted to the lowland humid tropics, ranging up to at least 1,000m.

Low Temperature Minimum soil temperature for germination is 16°C. For good growth, night temperatures should not fall below 13°C.

High Temperature An average temperature of 20-30°C is appropriate for growth, flowering, and pod development. Most cultivars are adapted to consistently high temperatures.

Soil A range of soil types give good economic yields but (not unexpectedly) well-drained, fertile substrates with adequate organic material and reserves of the major elements are ideal. Some cultivars are sensitive to excessive soil moisture, so well-drained, sandy locations are preferred. Neutral to slightly alkaline conditions, pH 6.5-7.5, seem best.

Related Species

The genus *Abelmoschus* includes from 6 to 15 species in the Afro-Asian tropics and North Australia. One that stands out is abelmosk or ambrette (*Abelmoschus moschatus* Medik.; syn. *Hibiscus abelmoschus*). Indigenous to India and cultivated (or weedy) in most warm regions of the globe, it is a low, slightly woody plant with a conical five-ridged pod containing numerous brown kidney-shaped seeds that are smaller than okra's. The seeds possess a musky odor and perfumers know them as ambrette ("abelmoschus" is from the Arabic "father of musk", with "moschatus" also referring to a musky smell). The plant also yields an excellent fiber and, rich in mucilage, is employed in upper India for clarifying sugar. One variety there known as bendi-kai is eaten fresh, prepared like asparagus, or pickled. The foliage and tubers of *A.m.* subsp. *tuberosus* have been consumed for centuries in Australia.

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SHEA

Shea may not be well known in a global sense, but it certainly is well known in West Africa. There, it constitutes the principal useful tree in a band of savanna nearly a thousand kilometers long. Traditionally, this large and treasured species, not unlike oak in general appearance, provided the primary edible vegetable fat to peoples inhabiting an estimated 1 million km^2 of wooded grassland. Early travelers observed that the cultures in that vast area—which collectively extends through 13 of today's countries, from Senegal to Sudan and Uganda—revolved around shea.[1] One such traveler was Ibn Batuta, who passed through in 1348; another was Mungo Park, the first European to trace the inland flow of the Niger River, in 1796.

Although few outsiders have heard of it, shea (pronounced "shay" or "shee") remains among West Africa's most extensive resources. All told, an estimated 500 million specimens of fruiting age exist, which probably equals the number of almond trees worldwide. The tree's fruits resemble large plums or very small avocados. The smooth-skinned, egg-shaped nut found at their center contains a kernel that yields the fat, which is widely used for cooking or for food. Indeed, West Africans use it much like Westerners use lard and butter.

This lipid is not liquid like a common vegetable oil. Rather, it is solid. Even in the tropical heat its texture ranges from a creamy paste to something like firm butter. A well-made sample taken from fresh nuts is white, odorless, and nearly tasteless.

It is difficult to overstate this vegetable fat's importance to the inhabitants of the semiarid zone below the Sahara. For millions living in this harsh location, where food is difficult to produce and life hard to sustain, shea butter is vital to everyday existence. It enhances the taste, texture, and digestibility of the major regional dishes. It is, for example, added to the staple known as tô—mainly to prevent that pasty porridge's surface from drying out but also to add flavor and consistency. Shea butter is also used when frying fritters, griddlecakes, and many other foods for use in the home or for sale in the markets.

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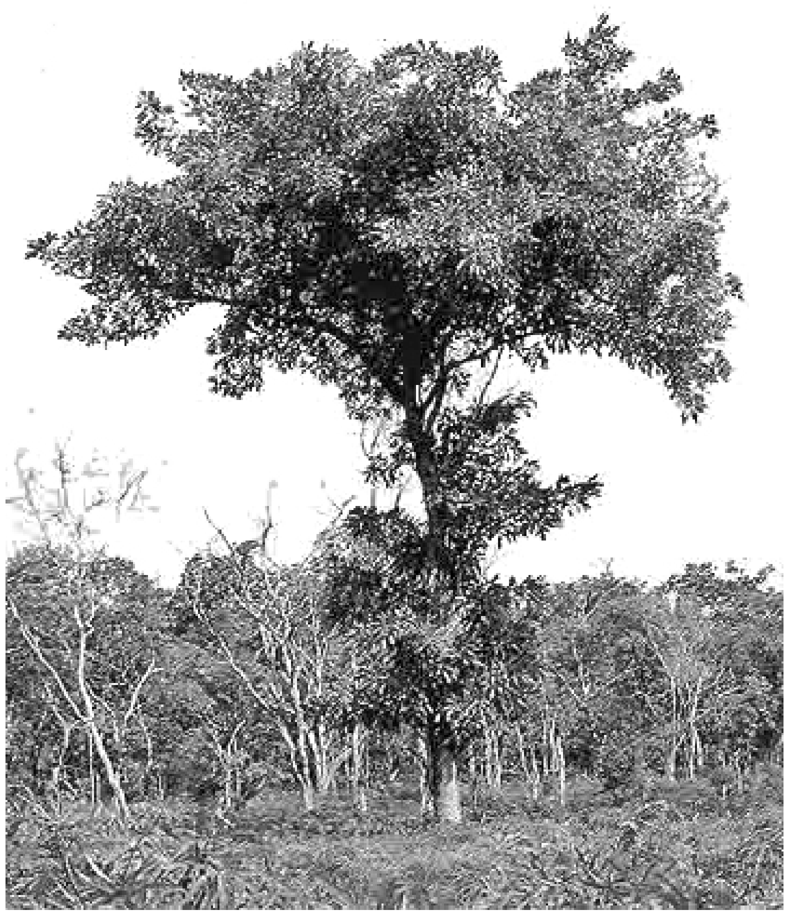
[1] Cultures historically reliant on shea include the Bambara, Fulani, Hausa, Mandingo, and Mossi (Burkina Faso's largest ethnic group).



Traditionally, the large and treasured shea butter tree provided the primary edible vegetable fat to peoples inhabiting a vast tract of wooded grassland this is vulnerable to some of the worst droughts of the arable world. It is often the only tree allowed to grow through its allotted lifespan, 400 years or more. Nutritionally speaking, shea is noteworthy for providing storable food that is capable of providing a steady source of buttery energy year-round. (E,C.M. Fernandes, ecf3@cornell.edu)

Beyond shea butter, this tree produces edible fruits, edible flowers, medicines, and several other necessities. And it does it all without human help or horticultural support in some of the most challenging inhabited sites on earth.

For all its international obscurity, shea is clearly very important. It is often the principal economic resource over extensive areas where little else saleable can be found or grown. It is the main profit center for the poor.

Throughout the Sahel, shea provides poor people cash. A survey in Burkina Faso indicated that the nuts provide 20 percent of family income, a figure that can be taken as generally representative of several neighboring nations and parts of nations. The Sahelian countries can hardly be called prosperous, of course, but without shea they would be much poorer. In Mali, field studies indicate that in areas where the shea is widespread 90 percent of the households engage in its processing, and that shea products contribute up to 60 percent of women's income. In years of poor production local market activity in notably affected.

Women are the ones who collect shea nuts. Women also extract shea butter. And women selling the butter in local markets are a commonplace sight. According to estimates, the tree provides more than half women's income in the rural Sahel. An observer has estimated that these nuts provide income to more than 2 million women, which is in all likelihood an underestimation.[2]

This tree also provides the Sahel with foreign exchange. Both the seed kernels and the butter are shipped to Europe and Japan, and now the United States, where they are processed into baking fat, margarine, cocoa-butter substitutes, and various beauty aids. Such exports have a long history. In Cleopatra's time, for instance, caravans bore clay jars of shea butter across the Sahara to Egypt where it was used in cosmetics, probably including those the queen herself applied. Since at least those dynastic days, shea exports have been providing West Africa with revenue. Currently Burkina Faso and Mali, which together ship over 100,000 tons of dried kernels annually, are the principal exporters. But shea is also an important Ghanaian export. Indeed, it's Ghana's third ranking cash crop; only cocoa and coffee exceed it in foreign exchange earnings. It is Burkina Faso's third largest export as well.

Although renowned for the food it provides, this tree's non-food products are valuable too. Across West Africa, shea butter is applied to the skin and hair. Refined in modern factories, it is incorporated into soaps, ointments, and skincare products of numerous kinds. It is also used to waterproof the walls of houses, so as to stop the infrequent downpours from washing the mud away. Furthermore, it is a staple of West African medicine. For thousands of years local healers have used the pasty solid to protect small wounds, heal infections, and soothe the aches of sprains and strains. Moreover, they prescribe it as a decongestant and an arthritis treatment.

People are not shea's only beneficiaries. This tree's environmental contributions are hard to overstate. For one thing, shea and locust (Chapter 11) commonly provide the only tree-cover across an area that is vulnerable to desertification. (the main zone of areas threatened with desertification is

[2] Hyman, E.L. 1991. A comparison of labor-saving technologies for processing shea nut butter in Mali. *World Development* 19(9):1247–1268.

north of where the shea is principally found; however, shea is primarily responsible for helping to prevent wind erosion and adding organic matter back to the soil). Its importance in this regard is locally understood. Laws forbid anyone from destroying a shea, and in most West African countries a person found felling one is prosecuted. As a result, shea trees are traditionally preserved during land clearing and farmers guard and tend the existing specimens, many of which are privately owned.

Perhaps it is no wonder this single species ends up forming pure stands often hundreds of hectares in extent. But beyond the solicitude of people and governments lies a probably more important reason: the thick and spongy bark. This covering is fireproof and it protects shea trees from the periodic blazes that incinerate other species.

Because of these natural and manmade protections much of the grassland below the Sahel is more like grassy woodland.[3] Shea turns it into a sort of park, commonly with as many as 20 to 25 mature trees per hectare savanna. Moreover, much of it is a farmed park and is in fact a creation of human selective pressure over generations. Shea are protected and other species culled out. This is one of the most widespread and striking examples of traditional agroforestry associations found anywhere on the planet. People plant their crops among the trees. Shea combines well with cereals; farmers usually protect their trees with great care. Even though anything casting shade on a crop reduces yields, research indicates that in the short run the value of shea products more than compensates for the lost production, while in the long run the soil-saving services conferred through the trees presence may far exceed any yield losses. This time-honored farm/park landscape covering major portions of the Sahel is a perfect example of large-scale agroforestry. The dispersed trees form an integral part of the normal cropping system and have done so for centuries, if not millennia.

A self-reliant tree species that provides food in the dry, drought-seared savanna would seem the ultimate in sustainable agriculture. Making the most of the difficult climate and the most of the largely worn-out soil, the trees need no care and may live several centuries.

But these upbeat points constitute only one side of the shea story. Based on its benefits shea may seem exceptionally promising, but that does not mean that overnight it can turn into a miraculous new resource. For this, there are several counterbalancing and discouraging reasons.

First, it is far from easy to build a bigger and better shea industry because the current trees are all wild. As a result, they are widely scattered and their yields vary up and down from year to year. A steady harvest can therefore never be relied on.

Second, this species has so far proven recalcitrant to research. It has been

[3] In the true Sahelian zone (200-600 mm rainfall), few shea are found. The classic ‘shea parkland is found further to the south, beginning in the northern Guinean zone and peaking in the Soudanian zone.

called temperamental and awkward and has only recently, for instance, been brought into plantations like oil palm or olive. Indeed, getting the shea tree to the point of formal cultivation presents so many challenges that both mainstream science and modern industry have largely passed it by.

Over the last 50 or so years there have been sporadic attempts to establish plantations, but in the past none was ever followed through to a successful conclusion. Indeed, only now do they seem commercially promising. For that, there is a simple explanation: The trees are very slow to mature. Moreover, the search continues for regular-fruiting varieties that can be relied on to yield fruit consistently year after year. It is little wonder, therefore, that many researchers basically gave up on this species. Most concluded that large-scale plantings would never be viable. In their frustration, they dubbed the shea tree "untamable."

Third, the production of shea butter remains mostly a cottage industry, which restricts its size and reliability. Worse, it is a process so onerous that to produce a liter of butter requires eight hours of very hard labor. Indeed, it takes so much time it must be put off until the dry season when not even farm chores can interfere.

The traditional process as used by Sahelian women is especially tedious. During the month or two in which the fruits are ripening, they visit the trees almost daily to collect any fallen ones before others or animals get to them. They set the fruits aside to ferment. Once the pulp has rotted a bit and the seed inside has separated, they remove the seed, wash it, and usually lay it in the sun to dry. Alternately, some seeds are dried, either by a briefly roasting in an oven or boiling followed by sun drying. Once they've been heated and dried this way, the seeds can be safely stored. They are also easily shelled to release the kernels inside. In the main processing step, those kernels are crushed or finely ground and heated once more. The resulting hot brownish mash is then churned and strained and kneaded for hours until the white pasty fat emerges.

This lengthy and exceedingly tiresome operation is done almost all by hand. Processing shea seeds is so laborious as to almost defy economic sense. Furthermore, poverty often compels women to sell their shea products to agents who then sell them on to exporters, who in turn sell them to the international food or cosmetic industry. The women—without whom shea products would be unavailable—thus profit little from their weeks of hard labor. One estimate of the maximum value of shea butter production per family per year was US$35. Even as grower cooperatives show increasing promise, old marketing patterns remain difficult to overcome

In sum, then, the shea tree is an enigma.

And the trends in modern times are making it ever more enigmatic. Following this long period of research neglect, consumers worldwide are discovering shea products for the first time and are demanding more. For one thing, food industries are finding special uses for shea butter in pastries

Although few outsiders have heard of it, shea (*Vitellaria paradoxa*) remains among West Africa's most extensive food sources. West Africans use its smooth-skinned, egg-shaped nut much like Westerners use lard and butter. For a vegetable lipid this one is unusual in that it remains solid even in a tropical climate. Countless Africans also use this so-called shea butter for skincare, and these days the product is going global and going upscale in some of the most expensive cosmetics ever formulated. High quality traditional shea butter sells for $0.75/kg in this Yendi, Ghana market (2003); shea butter produced by traditional methods is available online for $17/kg to more than $400/kg for the very highest quality material. (Peter Lovett)

(where it provides high dough pliability) and confectioneries (where it acts as a substitute for cocoa butter). Shea butter is also becoming a worldwide base for cosmetics and for treating such things as dry hair, dry skin, burns, and general dermatological ailments. The Internet is already overpopulated with peddlers pushing this newest skincare wonder.

Clearly then something needs to be done about this crop. Not only is the international demand rising, but the people living where shea grows are among the poorest and most desperate on earth. Any product capable of earning them an income and earning their countries foreign exchange is a critical resource.

Thus, despite abandonment by previous researchers and claims that the tree is untamable, action to advance shea production must be renewed. And it is finally happening. Some development agencies and many NGOs, focusing especially on women's issues, have initiated innovative programs. Some seem to be showing great promise, but scientifically almost everything remains to be done. Though shea butter (of highly variable quality) is appearing in many products worldwide, especially cosmetics and balms, no one—least of all the present writers—has a full grasp on exactly what all to do.

As noted, in the past few years the importance and potential of shea has drawn the attention of several government and nongovernment organizations, as well as commercial enterprises—especially as shea butter has become a premium ingredient in skin emolients. Appropriately, much of this work has been developmental rather than research; the journey is just beginning toward understanding this outstanding plant. In the Next Steps section below, we present some possible lines of investigation that could lay the foundation of a greater, more reliable, and more profitable resource—one that helps the people and the land, both of which are among the most defenseless on earth.

PROSPECTS

A holdover from the ancient times, shea butter is a still-unbroken link between the hunter-gatherer and agricultural civilization. But whether it finds an even greater place in the 21st century will still depend on raising and regularizing its production. How, when, and where shea will end is therefore more guesswork than judgment. It is even possible that shea will achieve a lesser place in this new century. The trees are being subjected to pressure from agriculture, drought, and a parasitic plant that sucks out their lifeblood. Shea butter production may actually decline in coming years. On the other hand, the prospects for greater production should rise as applications in the cosmetic and pharmaceutical industry develop. That would make shea butter commercially more desirable and it would not only give more cash to the producers but also more incentives for even greater development.

Within Africa

Humid Areas Probably poor. Shea is not known in locations where rainfall and humidity are high…but the reason behind that is not known either. Although the tree might possibly thrive under good rainfall, it seems unlikely that it would be a viable resource in any location where oil palm, other oilseeds, or cacao grow well.

Dry Areas Fair to good. This is the climatic zone where the tree finds its greatest prospects of course. Any tree that can provide resources in this hot, dry, exasperating locale would be welcomed. In this case, though, it is only in the dry areas of West Africa that it holds reasonable commercial promise. Parched locations in East and Southern Africa should try another crop if they want any commerce to eventuate.

Upland Areas Poor or limited. Shea grows at an altitude of 1,200 m in Cameroon, but most African highlands can find more reliable alternatives for producing the kind of products this tree yields.

Beyond Africa

Commercially speaking, shea is probably not yet worth trying. Even if it will grow well in a non-African setting, the combination of matching the climate, long lead-times for production, and processing challenges may keep shea at a competitive disadvantage outside Africa.

USES

The nuts and the butter tend to be used for different purposes when exported than when used locally. In Europe, for example, the fat is prepared by mechanical means and is used as a cooking fat, as a raw material for manufacturing margarine, and as a substitute for cacao butter in such things as chocolate and cocoa and used in cosmetics. The press cake or extracted meal ends up as cattle feed.

Below, we highlight the age-old West African uses.

Fruits The sweet, yellow or green pulp of the fruits is eaten when fresh. It is not unlike avocado and provides a valuable food during the early part of the rainy season, a time when other eatables are often scarce. Each tree typically produces 15 to 20 kg of fruit.

Seeds The kernel found within the walnut-like seed (that lies at the heart of the fruit) is, as we've said, the tree's major product. The kernels can be eaten fresh or roasted like almonds. The typical shea tree's annual yield of 15 to 20 kg of fruit corresponds to 3 to 4 kg of kernels or 1.5 to 2 kg of fat.

But the traditional methods of extraction recover only about half that. In other words, 4 kg of kernels generally yield less than 1 kg of shea butter.

Flowers The outer whorl of sepals (the calyx) is edible and is eaten especially in salads.

Shade The shea's spreading crown is much appreciated for the coolness it throws. In the torrid locations where this tree grows, people and animals both cherish its shade above almost everything else.

Wood The wood is hard and red in color. It reputedly resists termites, and finds various applications as a utility timber. For one thing, the wood is renowned for making tools. For another, it is used for coffins. In fact, it was the traditional material for ancient kings' funeral beds, carved from the wood of a noble old shea tree—a fact indicative of just how intimate and long the relationship between humans and shea has been. The wood makes good charcoal and fuel as well, although, because of its high value as a food, the tree is not felled for burning, even where fuel is in high demand.[4]

Cosmetic Uses Countless Africans use shea butter for cosmetic purposes, and these days the product is going global. Indeed, it is touted on the Internet as the only moisturizer or emollient a person could ever need. It has a mild, pleasant smell and combines well with essential oils for any desired fragrance. According to the breathless advertising, shea butter is the ideal treatment for dry, damaged, or aging skin and hair. Proof is lacking, but the possibility this is the truth seems real to users.

Medicinal Uses As noted, shea butter is locally used in medicines. It is particularly valued in ointments for boils and skin diseases. Despite a dearth of controlled experiments, it seems to enhance the healing of small wounds, cracks, crevices, and ulcers in the skin. Reportedly it contains no known allergens and is used even around the eyes. The tree's roots and bark have separate medicinal applications, which are less well documented or trustworthy. In addition, the wastewater from processing kernels is often used as a pesticide against weevils, apparently with good effect.

Other Uses Shea butter is said to be "the ideal treatment for drumheads." In addition, the leaves and young sprouts serve as forage. Although the foliage's palatability is said to vary greatly with the tree and the location, livestock generally like it. Sheep and pigs also eat the sugary pulp of any fruits that have fallen to the ground. The flowers yield nectar for bees. As

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[4] This is true even around Ouagadougou and Bamako, the capitals of Burkina Faso and Mali, for example. There, you see the trees standing full and tall.

Fresh fruits, fresh nuts, and dried shea kernels in Tenkodogo, Burkina Faso. "Shea butter" is extracted from the kernel, which contains 50 percent fat. It is an essential source of nutrition and cash for many families. Collected, processed, and marketed exclusively by women, shea is frequently their primary source of income and central to household security in homes from Senegal to Sudan. Today, exports for fine cosmetics and other value-added products are climbing rapidly and approach 10 percent of total production, which is around 600,000 t/yr. Development efforts are underway at many levels—from local cooperatives to United Nations' affiliates—to reinforce the vital economic links that shea creates among sustainable production, local labor, and export earnings. (Marlène Elias/Globalization-Africa.org.)

mentioned earlier, shea butter is daubed to waterproof mud walls. Most often, a coat of the fat is applied seasonally around the dwelling's doors and windows as well as along the base of the outer walls.

NUTRITION

Nutritionally speaking, this tree is noteworthy for providing a storable food that can provide a steady source of dietary energy year-round. Shea butter is made up mainly of triglycerides. Two fatty acids predominate: oleic (unsaturated) and stearic (saturated). The average fatty-acid composition has been given as: oleic, 40 to 55 percent; stearic, 35 to 45 percent; palmitic, 3 to 7 percent; linoleic, 3 to 8 percent; and linolenic, 1 percent.

Whereas the fatty-acid composition of shea and cocoa butter are fairly similar, shea butter has a much higher content of unsaponifiable matter, up to 17 percent unsaponifiables (8 percent on average). This non-fat fraction is composed of phenols: tocopherols, triterpenes (alpha-amyrin, lupeol, butyrospermol, parkeol), steroids (campesterol, stigmasterol, beta-sitosterol, alpha-spinasterol, delta-7-avenasterol), and hydrocarbons (2-3 percent karitene). It also contains terpenic alcohols.

HORTICULTURE

Strictly speaking, there is no such thing as shea horticulture. After all, there are no operating plantations. However, where people have tried planting the trees they have commonly employed a regular grid pattern with 10m x 10m spacing.

Shea seeds germinate easily when fresh but lose this ability quickly. The seedlings grow a long taproot, which endows great drought resistance, but makes them difficult to transplant. Seeds are therefore perhaps best planted *in situ*. Trees raised from seed mature very slowly, bearing their first fruits after 12-25 years and taking 30-50 years to achieve full productivity.

In principle, vegetative propagation could reduce that delay and lift the crop's potential in many other ways. So far, though, it has not been accomplished on any scale. This is an exciting time in shea propagation. Success with cuttings has been achieved, though methods presently seem challenging except with good skills and facilities. Grafting, though difficult and often inefficient, also works if practiced carefully. Air-layering has also been successful, yet it too has proven difficult to pull off reliably in practice. *In vitro* propagation is also reported. Just which methods to recommend are uncertain as of now; practitioners and decision-makers are advised to start first by searching the Internet and then consulting experts before making any long-term commitments.

In the wild, the tree sends up root suckers, a propensity probably providing the easiest way to produce shea vegetatively for small-scale commercial purposes. One researcher has recommended laying root sections (about 15 cm long and up to 1 cm thick) in nursery beds or large pots. After about two years, the resulting plants can be moved into the field. Although slow, this procedure is free to the local grower, and may remain the best method to increase planting material until elite selections become more widely available and reasonably priced.

Shea suffers from few diseases but some insect pests and four parasitic mistletoes (*Tapinanthus* sp.) cause it great—even mortal—damage.

HARVESTING AND HANDLING

The fruit is allowed to fall naturally from the tree and is collected from the ground. This occurs during the rainy season. Yields vary considerably. A harvest of 5-15 kg of nuts (kernels with shells) per year per tree is said to be average, but harvests up to 45 kg from trees that were protected and well-tended have been recorded.

Shea butter is extracted using several variants of the basic traditional method. The procedure used by the Mossi of Burkina Faso can be taken as representative: The freshly collected fruits are placed in pits and kept moist for several days to ferment. After the loosened pulp has been pulled off, the

Shea is often the principal economic resource underpinning the lives of those inhabiting vast areas where little else saleable can be found or grown. According to estimates, the tree provides more than half women's income in the rural Sahel. Foreign exchange is also earned: both seed-kernels and the butter are shipped to Europe and Japan, where they are processed into baking fat, margarine, cocoa-butter substitutes, and various highly touted beauty aids. (FAO photo/P. Cenini)

nuts are cleaned, boiled or roasted, and dried. They are then pounded and crushed to break off the hard brown shell and expose the kernel (or "almond"). Shaking and winnowing the mixture, as if it were grain, removes the particles of broken shell. The kernels are then air-dried to approximately 10 percent moisture, at which point they neither germinate nor decompose and can be safely stored for months without spoiling.

Next comes the main task. The dry kernels are heated over an open fire until they start "weeping." This exudation of oil means they have reached the temperature at which the solid fat liquefies: 38°C. The hot kernels are

then poured into a mortar and pounded using a heavy pole or flat rocks. This task is so long and so onerous that several women generally share the burden. The result is a reddish-colored paste. After cooling, this paste is rolled-out flat so the bigger impurities can be picked out. The fatty residue is then poured into a vessel and alternately rinsed in hot and cold water. Finally, it is kneaded, cooked in an iron pot, and steadily kneaded again with a rhythmic tumbling action until a white layer of fat rises to the surface. This "virgin" shea butter is skimmed off and wrapped tightly in leaves. This first-run, top-quality product may be stored for a long time. The rest is either reprocessed or discarded. Even such incredibly toilsome efforts recover only 36-40 percent of the fat in the kernels.

Of course considerable quantities of the kernels are also handled using modern methods. In Europe, especially, shea kernels are extracted using the expensive machinery designed for mass-processing other oilseeds: continuous screw press, filter press, and/or hydraulic presses. Industrial-scale extraction recovers at least 80 percent of the kernel's fat.

LIMITATIONS

Uncertainty over the harvest is certainly a prime limitation. Shea tends to bears fruit once every two or three years. In any year, two trees in three may produce almost nothing.

African mistletoe already affects a large portion of the shea population, including almost all of Burkina Faso's trees.

As has been shown, the fat is terribly difficult to refine. Making things worse, the nuts contain latex, which clogs filters and other machinery parts. Solvent extraction is also difficult, as the latex prevents the solvent from penetrating the mass. To reduce latex problems the nuts must start out bone dry, something not easy to accomplish in a village during the rainy season.

If not thoroughly purified, the fat goes bad. The decomposition begins in the fresh nuts. These are naturally low in free fatty acids when they fall from the tree, but if handled improperly they quickly turn rancid. It is recommended that freshly harvested nuts be boiled an hour (to denature the fat-splitting enzymes) and then dried in the sun.

NEXT STEPS

Since the 1940s and 1950s relatively little solid research has been undertaken on shea until recently. Many aspects remain poorly understood. In spite of its local and national economic importance, modern data on how best to produce it and its foods is still hard to come by. Further research is needed on virtually everything but, thankfully, much is at-last already underway. Though many of the challenges listed below may take years to resolve, anyone seeking answers today should first consult information and experts via the Internet.

Basic Aspects of the Tree The tree's biology and physiology are still very uncertain. To mention just one example, shea corymbs (the fan-shaped, flower clusters) carry several dozen flowers, but as far back as 1948 it was reported that only 2 to 4 of those flowers are fertile. Studies of pollination and reproductive biology could possibly point the way to increasing fruit production many fold and perhaps regularizing the annual yields as well.

Experts have yet to find the reason behind shea's irregular fruiting cycle. It seems probable that the bush fires and the hot dusty wind called harmattan contribute to the flowers and buds dying prematurely. Drought may also play a part. However, none of these is sufficient explanation in itself. There probably is a fascinating physiological explanation still awaiting discovery.

Basic research on the influence of climate and soil on the tree's productivity, growth, and unreliable bearing is needed as well.

Propagation Fresh seed germinates readily but viability declines significantly within a week or so unless the seed is cooled. The deep-rooted seedlings can be difficult to establish if transplanted. There has been some success with air-layering and grafting of superior clones, as well as tissue-culturing, but more experience is needed before standard practices are fully developed and acceptable. One special difficulty is the long period needed to reach fruiting age. Traditionally, shea was believed to take about 20 years to bear fruit, with full production only reached after about 50 years! Although experience generally bears out long lead-times, well-tended trees on a plantation at Sapone in Burkina Faso bore fruits after a dozen years. Whether such substantial differences are genetic or environmental requires further study, as it has significant bearing on prospects for domestication and non-seed propagation. There is also high yield variability among different trees, so further identification and propagation of selected germplasm is of high importance. The Cocoa Research Institute of Ghana has started one such a program, but it is a very long-term process. Vegetatively propagated materials may eventually reduce initial fruiting to only a year or two.

Regeneration of Parklands The only way to stop desertification across the Sahel is to protect the vegetation. Clearly, with its widespread presence and fire-proof trunk the shea should be in the forefront of any effort to slow, stop, or reverse the expansion of the Sahara effect. At the farm level, the low-performance individual sheas could be replaced over time or reworked by grafting on branches from high-performing trees. In addition, fallows could be seeded with quality planting materials. Additionally, means such as vetiver-grass hedges or fertilizer or pest controls could be applied to regenerate trees existing in the parklands.

Although shea has occupied the savanna parklands for millennia, the tree densities over the last few decades have declined in many places. Drought,

population pressure, and landuse change have killed some and decreased the regeneration of others. However, probably the greatest concern is the very high level of parasitism by the four mistletoes (*Tapinanthus* species). These parasitic plants are hard to combat. Approaches that have been suggested include herbicide control, physically removing the parasite from infected trees, killing the birds that pollinate mistletoe and disseminate its seeds, and boosting the populations of bird species that eat those particular seeds that land in the top of a shea tree. These and other possible methods need to be tested for safety and effectiveness, and quickly turned into practical controls.

Food Technology Traditional methods of extracting shea butter cannot meet today's needs, let alone tomorrow's. Researchers have identified several easier and more efficient ways to handle the nuts and still produce good quality butter locally. Although improving, these do not yet live up to their full promise, and continued diligent effort is sorely needed. Local production is crucial for a reason beyond local consumption: Africa exports more than 10 times more butter in seeds than as finished product, thus losing all that potential value-added profit

Using machinery to reduce the human drudgery is clearly necessary. This is not a novel notion. Mechanized shea processing has already been introduced to West Africa. Some uses sophisticated technology, some "appropriate technology."[5] Mainly, these approaches have involved mills to crush and grind the nuts, but there have also been attempts to use centrifuges to process the butter better and solar driers to dry the nuts. Solar technology has become very popular in West Africa, and solar driers are an especially intriguing possibility to ease handling the fresh kernels. This, as well as perhaps other techniques, would reduce the possibilities of the nuts decaying when they are stored in their shells, increase the efficiency of roasting and boiling the nuts, remove the tedium of extracting the oil, increase the recovery rate of the fat, and improve the storage qualities as the shea moves from savanna to salon.

Horticultural Development The current average production per tree is estimated at about 10 kg of fresh fruit. Clearly, this could be increased. A tree the size of an oak should be capable producing much more, and up to 200 kg has indeed been reported. Particularly good trees are well known and greatly prized in certain locations. Now is the time for a registry, so seed and cuttings can be collected and the production of quality plants for mass use made possible.

Overall "superiority" is not an easy thing to pin down, however. It might be based on the nut (the number, size, and butter quality, for instance). It

[5] The processing presses usually run on diesel or electricity, but now many manual models are becoming available.

might be based on the pulp (weight and sugar content, maybe). It might be based on the tree's growth characteristics. Individual trees with early, lengthy, or semiannual flowering may be of over-riding value for improved overall production. As standards are determined, the heritability of such production characteristics from superior trees raised through seeds also deserves study.

Arguably, the greatest of all research needs is vegetative propagation. This needs further research improvement, because it permits ready multiplication of superior trees. Perhaps the main problem behind all the vegetative methods is the plant's latex, which literally gums up the grafts. This is common to trees of this family (Sapotaceae). Indeed, another member of the family is sapodilla (*Manilkara zapota*), which is the original source of chewing gum. Sapodilla and sapote (*Pouteria sapota*) are commercially grown in tropical America. The special techniques developed for those latex-filled relatives might help open new possibilities for shea. Tissue culture should also be more widely explored, although here time-to-maturity once again becomes an issue, as does the added possibility of genetic off-types only revealing themselves after years of growth and investment.

There is also need for garden-variety horticultural research. With shea the possibilities for individual contributions are great. For instance, management of seedlings and trees needs improvement, and the use of mineral and organic fertilizers for faster growth and better fruiting deserve assessment.

Increasing Output At least in theory, production could be vastly increased in one simple way: collect more of the nuts. Presently, the natural wealth of the shea tree is not fully exploited, and much—even most—of the wild crop goes unharvested each year.[6] There are an estimated 94 million shea trees in Mali, for instance. Theoretically, therefore, that country alone could produce 80,000 tons of nuts a year, which could transform its economic standing in the world.

In this regard, more knowledge is needed on land tenure and how the tree rights are distributed among household members and community groups. This is important because new processing technologies and new market opportunities will make the crop more valuable, and inevitably lead to conflict over the trees' ownership. Research should be conducted to anticipate the consequences, good and bad, particularly to the traditional users, notably women. In many places, it may be simply that available labor is insufficient when the nuts fall, and simple techniques—manual or mechanical—that are used with other plants to collect "windfalls" may close

[6] In one survey it was found that only 43 percent of the total crop was harvested. Information from Brent Simpson.

this gap.

The cause is also partly economic. Current prices do not encourage farmers to fully utilize this resource. Demand and price are strongly influenced by the availability and cost of other vegetable fats, especially cocoa butter, so the price is not always controllable. Because of this and other factors, many harvests must be sold when local prices are low. Indeed, the women mostly sell on a seasonal basis, when the markets are already flooded with shea butter. Possible answers may include producer cooperatives, direct marketing, and shea-storage facilities. The small producers would then at least earn more money.

Product Research According to some observers, shea's future depends on developing uses for its unsaponifiable matter. This non-fat part of the seed displays several interesting physical and biomedical properties that could have pharmacological and cosmetic applications. These higher-value uses include prevention of skin drying, the soothing of sore skin, protection and lubrication, fast release and long retention of active ingredients, and high UV absorption.

Further research is therefore needed on the properties and applications of the unsaponifiable matter. Recognition of shea butter's unique properties and applications could result in big price increases at the point of sale. In theory, higher profits would then encourage capital investment in its production. And that could help fund research to make shea a booming resource for the whole Sahelian region.

SPECIES INFORMATION

Botanical Name *Vitellaria paradoxa* C.F. Gaertn.

Synonyms *Butyrospermum paradoxum, Butyrospermum paradoxicum* ssp. p*arkii, Butyrospermum parkii, Lucuma paradoxa* (Gaertn.) A. DC

Family Sapotaceae

Common Names[7]

Arabic: lulu, sirreh (Chad)
Bambara: se, berekunan, tamba
Burkina Faso: taanga (moore)
English: shea, shea butter, butternut tree, bambuck or galam butter
French: karité
Dioula: karité ("life")
Fulani: kareje

[7] The tree has many names in Africa. The English name shea, is derived from its Bambara name, se.

Ghana: sukpam (Frafra); nku or ngu (Ashanti); yokumi (Volta)
Hausa: mai, k'danya, bagay
Wolof: karité
Peuhl: kare, kolo

Description

This is a stout tree that can grow up to 20 meters tall with a trunk over a meter in diameter. It is deciduous, but never looks it because the new leaves arrive at the same time the old ones fall. The crown is dense and many-branched; its shape very variable. In adult trees, the bark is dark, thick and deeply cracked into squares, like crocodile skin. The leaves are tough and strap-like, mostly clustered at the ends of branches. There is an extensive root system, essential to help the tree survive the seasonal or multi-year droughts of the savanna climate.

The brownish or creamy-white flowers are also mostly clustered at the ends of branches. They seem pollinated by insects, mostly bees. The fruits ripen during the early rainy season. They are spherical or ellipsoid berries 3-6 cm long, borne on a stalk (peduncle) 1-3 cm long. The pulp is yellowish-green and sweet.

The nut at the center of the fruit consists of a thin brown shell enclosing a single, dark-brown, egg-shaped kernel, inside which is the fatty substance known as shea butter. The nuts are about 3 grams in weight. Sometimes they contain more than one kernel.

Distribution

Within Africa Shea occurs in the southernmost parts of the Sahel and the adjacent Sudan and Guinean savannas. Senegal is the western extent of its range.[8] Dense stands are found from Guinea through Mali, Burkina Faso, and Niger. The trees also occur in Guinea Bissau, Sierra Leone, Côte d'Ivoire, Ghana, Togo, and Benin as well as Nigeria and Cameroon. East of this region, there are scattered occurrences across Central Africa from Chad through Sudan to far-western Ethiopia, Uganda, and Congo.

Beyond Africa The tree is, as far as we know, unknown outside Africa except for a report from Honduras, where it is called "tango."

Horticultural Varieties

Although elite single specimens are known and reproduced by seed, and provenance trials of vegetative material are underway, there seem to be no

[8] In Senegal it grows only sporadically in the extreme southeast, around Tambakounda, Casamance.

true-to-type varieties. The species itself has been divided into two subspecies, subsp. *paradoxa* and subsp. *nilotica*. The former is found at lower altitudes (up to 600 m and occasionally much higher, but always west of the Nile drainage basin), is more drought-resistant, and takes longer to sprout (up to five months).

Environmental Requirements

Shea grows in the dry forests and savanna with a very marked dry season of 6-8 months. There are also periodic droughts that go on several years. It also occurs scattered in dry forests throughout the Sudano-Sahelian zone, but does not extend into coastal areas. It is a light-demanding species of open sites, mostly solitary, and over its principal ranges commonly forms pure stands.

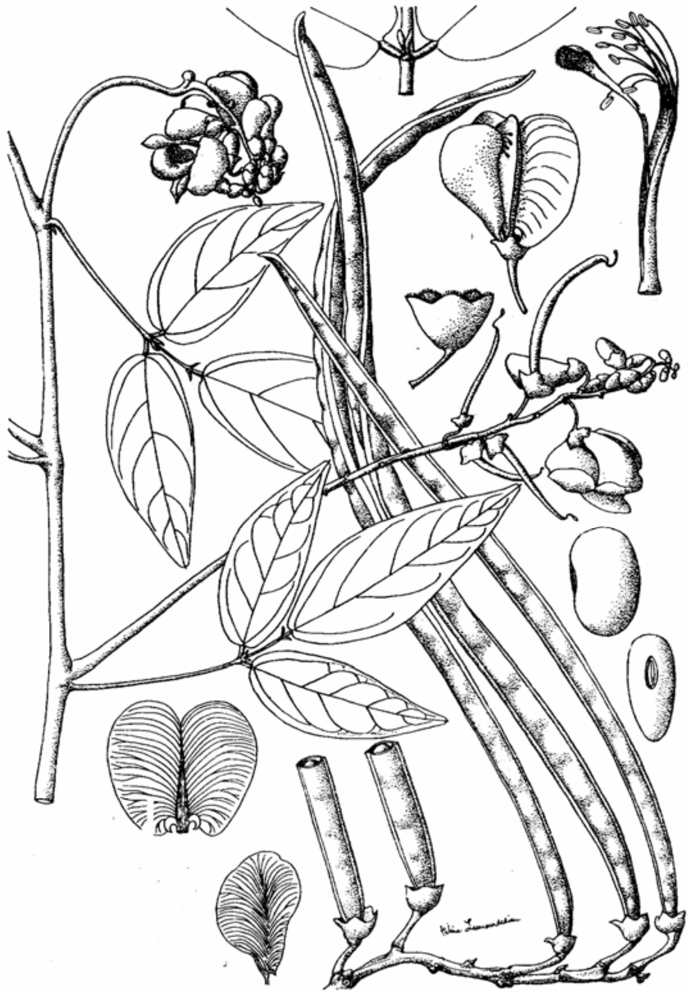
Rainfall Shea is found in areas with 400-1,800 mm rainfall per year. However, the trees are most common and healthy where they receive 600-1,200 mm and where the dry season lasts no more than 8 months.

Altitude Shea grows generally at low altitude, although on Cameroon's Adamaua Plateau it ascends to 1,200 m above sea level.

Low Temperature It grows in areas characterized by average annual temperatures of 24-32°C. The minimum is reported to be 21°C.

High Temperature Temperatures where shea is found commonly climb into the lower 40s.

Soil Shea occurs naturally on the dry slopes of the savanna zone, but not in alluvial hollows or land subject to flooding. It is found on various soil types but seems to prefer dry and sandy clay soils with a good humus cover. Nonetheless, it tolerates stony sites and lateritic subsoils, although its yields may not be great.



Sphenostylis stenocarpa (Hochst. *ex* A. Rich.) Harms

18

YAMBEAN

The plant known internationally as yambean is arguably one of the most interesting of all the world's new food crops.[1,2] This species, which hails from the Americas, looks like a bean plant above ground but is actually grown for the swollen roots it produces below ground. Since the dawn of history these yam-like tubers have fed tropical Americans. Then Spanish galleons[3] carried the seed across the Pacific, and this productive, palatable, and nutritious legume subsequently spread through Asia and became a market-garden favorite from China all the way to India.

In recent decades yambean has taken on renewed momentum and is now among the world's fastest rising new crops. Already it is the top selling specialty vegetable in the United States, its tubers being sold in many (if not most) U.S. supermarkets under its Mexican name, jicama. Americans buy the round, squat tubers for use in salads, for replacing scarce water chestnut in Chinese cooking, and for a low-calorie snack food. Demand has risen to such an extent that Mexico now exports half a million tons annually.[4]

In Europe, this food is catching on, too. Part of Thailand's large yambean output, for instance, is now shipped to many Asian stores in major European cities. This American crop has even entered production trials in Portugal, where, under conditions seemingly so different from its native tropical habitat, it has demonstrated very impressive yields: 54 tons per hectare, with up to 24 percent dry matter containing 10 percent crude protein.[5]

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[1] Several *Pachyrhizus* species go by this name, but the best known and best developed yambean is *Pachyrhizus erosus*. It mostly goes by local or indigenous names, including fan-ko (China), sankalu (India), sinkamas (Philippines), dolique tubereux or pais patate (French), Knollige Bohne (German).

[2] Information in this chapter relies heavily on Sørensen, M. 1996 *Yam bean (*Pachyrhizus *DC.)*. International Plant Genetic Resources Institute, Rome, and personal communications with this tireless Danish crop champion.

[3] Amazingly, these galleons crossed the Pacific from Mexico to the Philippines annually without fail for 400 years.

[4] Its wholesale price has reached $2.50 a kilo, an amazing figure for a root crop traded in bulk.

[5] The yambean here was the Andean species (*Pachyrhizus ahipa*), and the range of

Seeds of three varieties of African yambean from farmers' fields in Nigeria (soybean lower-right for comparison). The seeds are notably nutritious, and experiments in Nigeria have yielded of 2 tons per hectare, an exceptional amount for an undeveloped legume. Starting from such a base, the African yambean—given good research support—would seem capable of ultimately yielding as much as the best bean crops. (Thomas Betsche)

More to the point, though, is the fact that during the last few years yambean has also arrived on Africa's shores. Here, too, it has been a smash hit, creating what a researcher describes as "remarkable success in a number of West African countries." Again, yield was the major draw. In trials carried out in Benin, for example, two genotypes produced around 80 tons of tubers per hectare.[6] At separate locations in Senegal, the per-hectare production was 40 and 100 tons.[7]

protein contents, measured on a dry-matter basis, was 9.6-11.1 percent. The plantings were made in Tras-os-Montes, a northeastern province of Portugal where the climate is distinctly Mediterranean.

[6] Both the Mexican yambean (*Pachyrhizus erosus*) and the Amazon yambean (*Pachyrhizus tuberosus*) were introduced to Benin. The yield mentioned here was measured in two varieties of the Mexican species. In addition, in Benin one Haitian cultivar of the Amazon yambean produced a yield of 70-80 tons per hectare, which is certainly not to be sneezed at. Further introductions have been made to Congo and Ghana. In tests in Mexico, the local yambean has yielded 160 tons of tubers per hectare, perhaps a world food-production record.

[7] The Senegal figures were recorded on research stations at Bambey and Tiago, respectively.

That is an enormous quantity of food for such a small area to produce and, although the tuber has a rather exotic texture and taste, West Africans have taken to it. Indeed, thanks to local media coverage, it has generated such intense public interest that the biggest problem, so an observer reports, is finding enough seed to meet the need. Stemming from this has come one unforeseen consequence: “A peculiar situation has arisen,” the observer writes, exhibiting great circumspection, “with several of the field trials subjected to ‘unauthorized testing and sampling’ at night by local farmers!”

Given all these developments across the various continents, it seems little wonder that this species is steadily climbing upward toward becoming a truly global resource. But a seldom-recognized fact is that Africa has its own counterpart. The so-called African yambean (*Sphenostylis stenocarpa*) is not uncommon in central and western Africa, especially southern Nigeria. Outside tropical Africa, however, no one has seen it and few heard of it. Indeed, not only has the African yambean not taken even a baby step toward being a global resource, it actually is moving in the opposite direction…toward extinction.

Although classified as belonging to a different genus, the African yambean is closely related to the American version and also is grown for its fleshy swollen roots. Its tubers, however, are elongated and look more like sweet potatoes than yams. In nutritional terms, they are a class above the mainline root crops, containing more than twice the protein of sweet potatoes, yams, or potatoes and more than ten times that of cassava. Moreover, the protein is of exceptional nutritional quality, superbly complementing the proteins of maize, sorghum and the other staples. Eating African yambean together with those major foods helps provide the body a “complete protein.” The combination, in other words, closely matches the chemical requirement for constructing the thousands of separate proteins human bodies need to make constantly.

And that is just one of the surprises this minor and almost lost crop conceals. Another is that this almost unknown African resource surpasses its transatlantic counterpart by producing both edible seeds and leaves in addition to the edible tubers.

All yambeans are unusual in that they are legumes, a plant family renowned for peas, beans, soybean, peanut, and other nutritious seeds, but not for edible roots. Yet the yambeans’ swollen underground stems are succulent, white, sweet, mildly flavored, and crisp as a fresh-picked apple. They can be eaten out of hand. They can be used to add crunch to green salads and fruit salads. They can be steamed or boiled, and have the unusual property of retaining their crispness even under conditions that convert potato to mash. In cooked form they taste like potato, but whereas it averages 5 percent protein, African yambean tubers have from 11 to 19 percent protein (on a dry-weight basis).

And good taste and good nutrition are just the start of the appeal. African yambean appears to combine qualities that make it attractive to the farmer, the processor, the consumer, AND the environment: good adaptability to a wide range of climates and soils, reliable yield, a good balance between protein and starch, agreeable taste, good shelf-life, biological nitrogen fixation, and energy efficiency.[8]

All this makes one wonder why a species combining the reliability of a root crop with the protein content and high sustainability of a legume is not better known. Certainly, Africans familiar with the plant regard it highly. Trouble is, only a few of the continent's 600 million inhabitants have heard of it, let alone tasted it. It is mainly restricted to pockets of West and Central Africa, where smallholders grow it exclusively for their own use. Thus, even within the region that knows it best much of the populace is unaware of the botanical gem in their midst.

That botanical gem remains unpolished, however. Perhaps because it seldom enters commerce to any degree, it has received little formal recognition from the agricultural authorities. Indeed, there is so little understanding of it that only sketchy summaries and a scattering of research papers highlighting specific technical features can be found in the international literature.

Yet African yambean is not unimportant in people's lives. Cultivated in Nigeria mainly for seed, it is also grown for tubers in Côte d'Ivoire, Ghana, Togo, Cameroon, Gabon, Democratic Republic of Congo, Ethiopia, and parts of East Africa, notably Malawi and Zimbabwe.

Moreover, the plant is adaptable, and capable of growing anywhere that common yam is cultivated.[9] Indeed, it could be grown in many more locations than that, not to mention grown much more successfully in those locations where it already exists. A vigorous vine that climbs and twines to heights over 3 m, the plant thrives in weathered soils where the rainfall can be extremely high. It tolerates even the acid, infertile, highly leached sites that are the humid tropical lowlands' special curse.

Part of the reason for this adaptability to bad substrates is that like other members of the legume family, the African yambean enjoys a symbiosis with bacteria that fix nitrogen from the air. The invisible bacterial microbes inhabiting its roots relieve the farmer of the necessity to supply additional nitrogenous fertilizer. They also make the plant a fine candidate for sustainable development purposes. This is, in other words, a food source that supports itself while helping both the soils under it and the species that succeed it.

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[8] Regarding this last point, the tubers can be consumed fresh, thereby saving wood and other cooking fuels. Soaking overnight is very useful to reduce cooking time.

[9] In many cases both plants are cultivated together, and one theory holds that the plant's English name comes from this combination. More likely, though, the name developed because the plant has "yams" on bottom and "beans" on top.

And the African yambean is no slouch in the yield department, either. It produces its seeds, tubers, and biomass in abundance:

As far as the seeds are concerned, experiments in Nigeria have demonstrated yields of 2 tons per hectare,[10] an exceptional amount for an undeveloped legume. Starting from such a base, the African yambean, given good research support, would seem capable of ultimately yielding as much as the best bean crops. As mentioned, the seeds are notably nutritious, with crude-protein levels ranging from 20 to as high as 29 percent. Although this is less than the amount in soybeans (38 percent), the protein contains levels of essential amino acids likely to make African yambean seed the soybean's nutritional equal. Lysine, for example, comprises up to 8 percent of the protein, and methionine and cysteine together may comprise 2.4 percent.

But it is the below-ground product that is of greatest immediate interest. The tuber yield varies between cultivars and has not been pinned down with precision. Nonetheless, it is generally high. If grown in pure stands, 100,000 plants per hectare is a reasonable field density, and each produces up to 500g of tubers. This already good figure can undoubtedly be raised—possibly dramatically—merely by preliminary research attention.

Of the biological nitrogen fixation, only a few details have been reported. Hopefully, the actual amount fixed can eventually be raised to a level similar to that of its American counterpart: 200 kg of nitrogen per hectare.[11] In that transatlantic species, about half the nitrogen, or more than 600 kg protein per hectare, accumulates in the tubers. This is an amazing amount for a hectare of root food. It approaches or exceeds the stellar seeds of soybean and peanut, which are considered world protein-production leaders.

Any root crop even vaguely capable of delivering record quantities of protein from soils normally considered marginal would seem to deserve intense global attention. For all its potential, though, African yambean remains a neglected, even primitive, resource. There has never been a concerted steady effort to advance it, despite the fact that throughout the tropics root foods are increasingly sought. Because of this neglect, the farmers who know it best are switching to crops for which more help is available, and sadly their heritage of seeds and age-old wisdom with the crop are slowly fading away.

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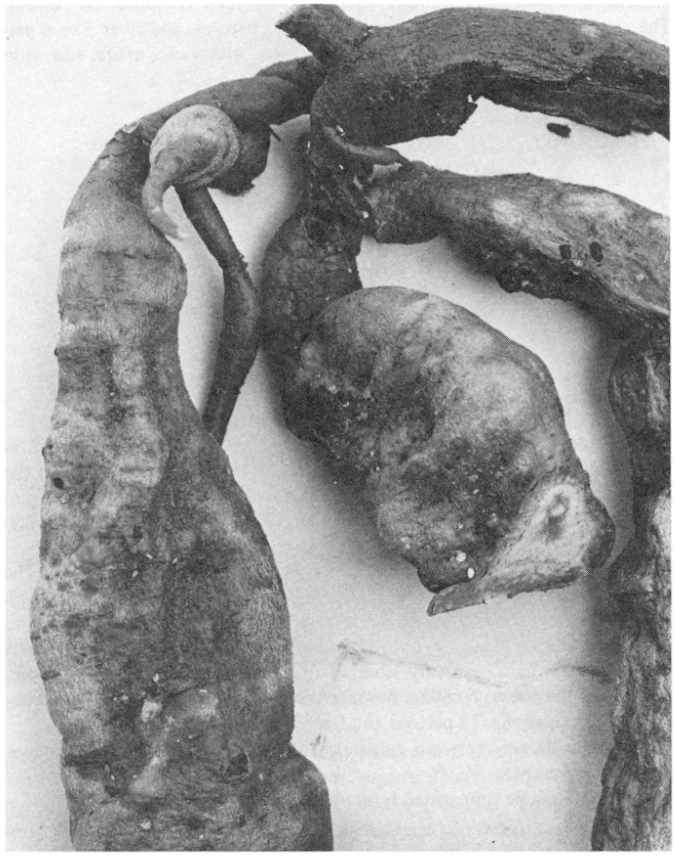
[10] Out of 63 lines from a germplasm collection at the International Institute of Tropical Agriculture in Ibadan, Nigeria, the most productive line yielded 1,860 kg of seed per hectare. Yields of 2,000 kg per hectare have been recorded at a research station in Nsukka, Nigeria.

[11] These figures, measured in three cultivars of the Mexican yambean, *Pachyrhizus erosus*, were 163-216 kg of nitrogen per hectare, of which 70-75 percent was produced through fixation of atmospheric nitrogen (based on isotopic ^{15}N methods). Castellanosa R., J.Z., F. Zapatab, V. Badilloa, J.J. Peña-Cabrialesc, E.S. Jensend, and E. Heredia-García. 1997. Symbiotic nitrogen fixation and yield of *Pachyrhizus erosus* (L) urban cultivars and *Pachyrhizus ahipa* (Wedd) Parodi landraces as affected by flower pruning. *Soil Biology and Biochemistry* 29(5-6):973-981.



African yambean tubers, with their succulence and crunchy texture, could appeal to millions of palates. Moreover, it grows easily and is well suited to the difficult environment of the hot wet tropics where the climate and conditions now constrain local diets to far less nutritious foods. (International Grain Legumes Information Centre)

This trend must be changed. A plant that perhaps could benefit millions of the malnourished deserves urgent attention. The highly efficient way in which it absorbs nitrogen makes it an especially attractive tool for helping farmers whose land is worn out. Moreover, it grows easily and is well suited to the difficult environment of the hot wet tropics where the climate and conditions now constrain local diets to far less nutritious foods. And the tubers, with their succulence and crunchy texture, could appeal to millions of palates. Possibly the African yambean could do much more than just help subsistence farmers eat better…it might make a valuable cash crop across regions that desperately need a biological fulcrum for leveraging rural development upwards.

PROSPECTS

Given the fact that little has yet been done to advance this neglected vegetable it is hard to project how far it might ultimately go in helping humankind. Nonetheless, some sense of the promise can be grasped by a quick comparison with its transatlantic counterpart, which as noted has become one of the fastest rising new food crops and is already a megamillion-dollar resource.

Within Africa

Humid Areas Excellent. The plant is found growing through much of tropical Africa and is fully at home in lowland areas where the rainfall is high and nutritious crops hard to come by.

Dry Areas Unknown. In Nigeria the species is cultivated from the tropical forests to at least the savanna's edge. The issue of growing it in dry areas is less one of biology than of economics; root crops typically are drought resistant but they need copious water to yield profitably.

Upland Areas Excellent. Although often classified as a low-altitude legume, it seems little affected by height above sea level, and flourishes at elevations up to at least 2,300 m.

Beyond Africa

In other tropical regions of the world this plant would likely thrive, but no one has tried to find out.

USES

Seeds and tubers represent the primary food, although the plant also has potential utility producing feed for livestock and green manure for soil restoration.

Seeds The seeds may be eaten alone or in soups, and are commonly served with yam, maize, or rice. They are said to be delicious and to be "often preferred over other types of beans."[12] The leathery or slightly woody

[12] Although "field reports" are overwhelmingly positive, antimetabolic factors common to other pulses (such as soybean) have been found in the laboratory (see Limitations), and stomach cramps, diarrhea, and dizziness have been reported from Nigeria (Azeke, M.A., B. Fretzdorff, H. Buening-Pfaue, W. Holzapfel, and T. Betsche. 2005. Nutritional value of African yambean (*Sphenostylis stenocarpa* L): improvement by lactic acid fermentation. *Journal of the Science of Food and Agriculture* 85(6):963-970; an online overview, "Food safety and security: Fermentation as a tool to improve the nutritional value of African," is available at tropentag.de/2005/abstracts/full/463.pdf). It is unclear

pods are typically bundled together and hung over the fireplace, where they stay safe until consumed or sold. The beans extracted from the dried pods are prepared in several ways. Many are partially roasted over a fire and eaten together with palm kernel. Others are soaked several hours, boiled 4 to 6 hours, and eaten like common beans. In another procedure, they are squeezed with palm oil and chili pepper as well as various spices and vegetables to form a paste, which is wrapped in banana leaves and heated over the coals. In every case, so it is said, African yambean seeds make a nutritious, filling, and tasty meal.

Roots The tubers are eaten either raw or cooked. The exact details are still unclear, but some idea of their eventual utility can be inferred from the yambean in Mexico, where:

- Raw tubers are cut into sticks and sprinkled with lime juice and chili;[13]
- Fresh tuber slices are added to salads of both the dinner and dessert kinds;
- Cooked tubers are used on their own or with other vegetables to prepare soup;
- Chopped tuber is added to Oriental stirfries;
- Tubers are grated and boiled in milk to create a tasty drink;
- Sliced or diced tubers are pickled with onion and chili to form a popular snack food; or
- Tuber segments and green beans are preserved in vinegar as a sort of three-bean salad.

Leaves Although the leaves are said to be edible, nothing more than those few words are on record, so the extent, mode, and safety of eating them remain uncertain. The leafy vegetation remaining from the harvest provides useful fodder. Likely, it is very beneficial to livestock, due both to its protein content and the massive quantities produced.

Sustainable Agriculture Of all the 17,000 nitrogen fixing species in the plant kingdom, yambean seems to be among the most efficient. On a per-hectare basis, the American species has been recorded as regularly producing 120-150 kg of nitrogen.[14] This is higher than that recorded in other grain-legume residues, and gives yambean an important role in crop

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how genetically or geographically widespread these factors are (see Next Steps).

[13] On the streets of places like Mexico City, vendors sell these as a cooling snack for hot and harried passersby.

[14] The plant populations in the trials were 110,000 plants per hectare and the flowers were pruned to force greater tuber growth. Castellanosa R., op. cit.

rotations, a fact known for centuries in tropical America. In many traditional farming systems in Mexico, for instance, the crop is employed to restore soil fertility after years of cropping maize and cassava and cotton and other nutrient-draining species. African yambean could well prove to have a comparable soil-restorative capacity. Already, there is preliminary evidence that African yambean could make an excellent species for crop rotations, for ground cover, for binding soil and related purposes.[15]

Other Uses With its prolific spattering of large, colorful, dangling flower clusters—pink, purple, or greenish white, among other hues—this vine makes a vivid ornamental, reminiscent of wisteria (although the flowers are much smaller and the inflorescences are upright, rather than hanging).

NUTRITION

African yambean is a nicely rounded non-fat food: from 50-75 percent carbohydrate, 20-25 percent protein, around 1 percent oil, and 5 or 6 percent fiber, all providing nearly 400 calories per 100 g dry-weight. Although the protein is produced in copious quantities, that is not necessarily the ultimate measure of a proteinaceous foodstuff. More important is the protein's nutritional *quality*, because a protein lacking certain minor components is nutritionally next to useless. In a protein, quality is judged by the incidence of a few amino acids, and many plant proteins, being deficient in lysine and methionine, are low in nutritional quality. On the other hand, African-yambean seed protein contains those two in abundance: lysine 7-8 percent and methionine 1-2 percent. And the levels of the other essential amino acids enhance that already exceptional condition. In one seed sample, for instance, the overall complement was: cysteine 1.9, leucine 6.6, lysine 8.3, methionine 1.2, phenylalanine 4.8, threonine 3.3, and valine 4.1 percent.[16]

As mentioned, the tubers are nutritious too. The raw protein in those swollen root tissues amounts to 11 to 19 percent, which puts the plant into a nutritional class above the major root crops. The tuber protein is also of high quality: cysteine 1.8, isoleucine 4.5, leucine 7.7, lysine 7.6, methionine 1.7, phenylalanine 4.5, threonine 4.3, and valine 5.5 percent. Adding to the tubers' nutritional contribution is their 63-73 percent content of carbohydrate and their 3-6 percent fiber. The starch alone has been put at 65 to 70 percent and about 370 overall calories.[17]

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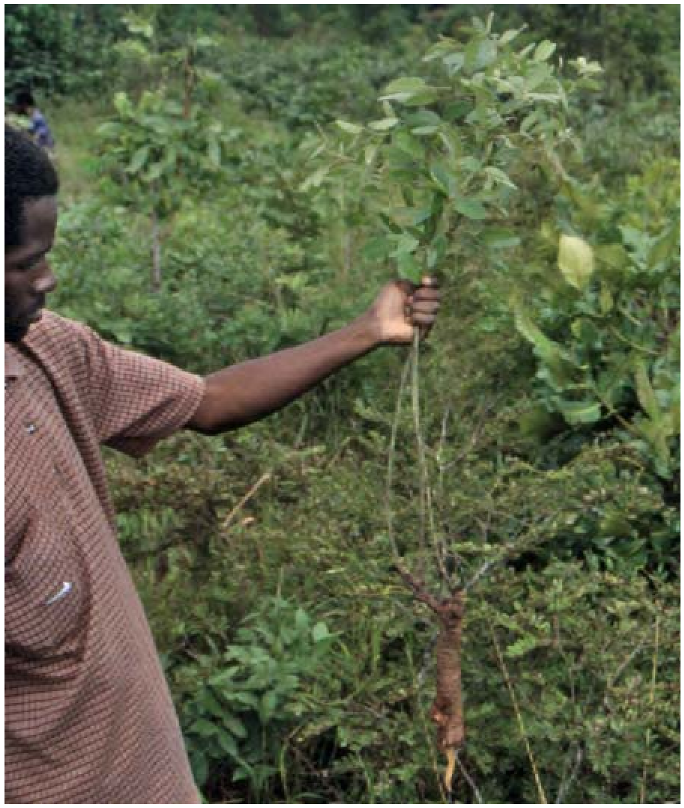
[15] Contributor Dieter Kleiner reports, "we've made a small experiment which demonstrates that *S. stenocarpa* is an excellent biofertilizer."

[16] All figures are given in g per 100 g protein. Ezueh, M. I. 1984. African yam bean as a crop in Nigeria. *World Crops* 36(6):199-200.

[17] These tuber component figures are also from Ezueh, ibid.



Chimaliro Forest, Kasungu Province, Malawi. African yambean is a legume whose fleshy swollen roots look something like sweet potatoes but are succulent, sweet, and crisp as a fresh-picked apple. In nutritional terms, they are a class above the mainline root crops, containing more than twice the protein of sweet potatoes, yams, or potatoes and more than ten times that of cassava. Moreover, the protein is of exceptional nutritional quality, superbly complementing the proteins of maize, sorghum and the other staples. In addition, both seeds and leaves are edible. And the African yambean is no slouch in the yield department, either. It produces its edibles in abundance, and seems capable of delivering record quantities of protein from soils normally considered marginal. (Søren Døygaard)

The true importance of the quality proteins from both beans and tubers lies in their ability to complement cereals such as maize and sorghum as well as roots such as yam, cassava, and sweet potato. When measured against the uncompromising necessities of human nutrition, those staple foods are deficient in essential amino acids. This fact of nature creates a nutritional crack in the foundations of Africa's food supply because people living primarily on cereals and roots (which includes many of the poor, the sick,

and the very young) can run out of a dietary essential amino acid. When that happens their bodies stop producing *all* protein—brain, muscle, hair, antibodies, enzymes, blood cells, skin, and the rest. In such situations, the addition of even a small amount of the missing essential amino acid from, say, yambean raises the overall protein effectiveness out of all proportion and restores the bodily processes to normal operation.

For children, especially, yambean may be valuable in this regard. In normal situations, adults eat cereals with sauces that contain small amounts of protein and vitamins. But children typically find the sauces too peppery and are served cereals without that special nutrient supply. Adding some yambean would make up for the loss. In addition, children can nibble on the raw tubers to get quality protein.

HORTICULTURE

Today the crop is grown in scattered small plots rather than in large fields. Although it can be cultivated alone, it is mostly grown with yam or maize. At the beginning of the wet season farmers plant it using seeds, small tubers, or pieces of root. Like yam, it is normally planted on ridges or little hills. It is also normally supported on trellises or stakes—often the same ones supporting the yam vines. However, tests in Nigeria suggest that it grows and yields tubers satisfactorily even unsupported.

If the maximum yield of tubers is desired, the above-ground parts should be severely pruned back. We don't know how widespread this "reproductive pruning" process is in Africa, but in the Americas it is considered the key to achieving big yambean tuber crops. There, both the flowers and flower buds are pruned as many as four times a season, with the first cut being made about 2 months after planting. The target is the reproductive parts; a few flowers may be left for seed production, but the rest, and the main growing shoots, are rigorously removed. The plant responds by pumping its energy into the parts underground.

Normally no special irrigation is applied. Nor is nitrogenous fertilizer needed, although experience in Mexico suggests that a shot of phosphorus could be helpful.

Pests are seldom serious, and typically they are the same ones affecting other legumes in the area. One report lists the African yambean's major insect attackers as bean pod borer (*Maruca testulalis*), stem-boring beetle (*Sagra adonis*), and the variegated grasshopper (*Zonocerus variegatus*). The exact mix of pests, however, is likely to vary with location. Controls that work on other legume crops should prove equally effective on African yambean.

Diseases are also similar to those of other local legumes. The main fungal threat is downy mildew (*Phytophthora phaseoli*). An unidentified yellow mosaic virus has been observed attacking the plant in Nigeria.

Like most legumes, this one is highly susceptible to nematodes.

HARVESTING AND HANDLING

The African yambean typically begins flowering 80-120 days after planting. Pods start maturing at about 150 days after sowing. From then on, flowering and pod formation continues for as long as the climate remains conducive. As a practical matter, though, harvesting usually ceases after 60 days.

The tubers develop more slowly than the flowers, normally taking 5 to 8 months to swell to harvestable size. Most are dug up toward end of the rainy season. They can, however, be harvested early (if local preferences encompass small or medium sized tubers) or they may be left in the soil for a time after the rains cease.

As to handling the tubers, methods developed for the related species in Mexico probably apply. There, the ridges or little hills of soil are loosened with a hoe or with a crossbar mounted on a tractor. Each tuber is then lifted by hand, and the vegetative top is removed with a pair of shears and left in the field for later use as forage or organic fertilizer. Finally, the tubers are collected, sacked, and stacked for shipment.[18]

The optimal storage temperature for the Mexican tubers is given as 12.5-17.5°C. And the only treatment given them is washing, trimming (to remove roots and stem parts), and dipping in hypochlorite solution to sterilize and bleach the surface. The tubers then remain usable for about a month, provided they are kept indoors and well ventilated. The African yambean tubers can probably be treated similarly.

LIMITATIONS

A number of limitations need be kept in mind:

- The crop is slow to mature and is considered sensitive to daylength.
- As in many beans (and other foods), the raw seeds contain trypsin and alpha-amylase inhibitors, tannins, oxalates, saponins, and phytic acids, as well as "potentially very toxic" cyanogenic glycosides (especially in white seed) and flatulence-causing alpha-galactosides.[19] These levels were improved somewhat by thorough cooking (see below), and the levels likely vary significantly among different genotypes (as in common and lima bean). An alternate route suggested by the authors was *Rhizopus*- and lactic-acid fermentation, as used with soybean, which greatly reduces most of these antinutritional factors with much less energy cost, while yielding additional fermented foods for this part of the world, where such delicacies are already

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[18] Alternatively, they are loaded straight into trucks and whisked to a local market, to Mexico City, or to the northern border for cleaning and repackaging, and onward shipment to US supermarkets.

[19] Azeke, et. al., op. cit.

so popular. Others have shown it makes good dawadawa paste.[20]

- The dry beans need lengthy cooking, traditionally 4-6 hours (like most beans) but much longer (up to 12) to apparently have significant impact on undesirable compounds.[21]
- Certain peoples prefer certain seeds. Southern Nigerians, for instance, like darker types, while northerners want brightly colored seeds.
- High moisture content makes yambeans shrivel and lose condition more quickly than the mainstream root crops.
- Bean weevils (bruchids) can attack the seeds in storage, as they do other beans.
- The beans reputedly "sit heavy in the stomach" and are said to cause thirst and wind.

NEXT STEPS

Clearly, this crop deserves the attention of modern science. There is little doubt that both basic and applied sciences can dramatically increase its productivity and usage. As of now, though, this foodstuff is known only in Africa, so most initiatives must be local.

Many research avenues can help make the crop more productive and more useful. Some are presented under the headings below.

Surveying the Scene A first priority should be the development of baseline African-yambean knowledge, including such things as geographic limits, traditional uses, and standard cultivation practices. Such basic expeditions can be simple, inexpensive, and enlightening.[22] An initial survey in Ghana, for example, found "[African yambean] is used extensively in various dietary preparations and has potential for supplementing the protein requirements of many families throughout the year." Important actions include:

- Initiating countrywide searches to locate the crop and its farmers;
- Documenting the methods traditionally employed for growing it;
- Publicizing the methods traditionally employed for cooking the different parts (including leaves);
- Assessing natural genetic differences throughout its range; and
- Collecting and evaluating representative germplasm.

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[20] Wokoma, E.C. and G.C. Aziagba. 2001. Sensory Evaluation of Dawa Dawa Produced By the Traditional Fermentation of African Yam Bean (*Sphenostylis Stenocarpa* Harms) Seeds. *Journal of Applied Sciences and Environmental Management* 5(1):85-91
[21] Ibid.
[22] G.Y.P. Klu, H. M. Amoatey, D. Bansa, and F. K. Kumaga. 2001. Cultivation and use of African yam bean (*Sphenostylis stenocarpa*) in the Volta Region of Ghana. *Journal of Food Technology in Africa* 6(3):74-77

The pool of knowledge resulting from such initiatives can provide insight into the African yambean's existing limits, possibilities, and extension priorities. It will also point out ways by which farmers can be helped to manage the plant more intensively, more securely, and more productively. It will, in other words, provide preliminary guidance on the present status and the future steps, including best practices for planting, cultivating, controlling pests and diseases, harvesting, handling, and cooking the crop.

Support for Farmers Preliminary surveys should be quickly converted into advice to help those who are the keepers of Africa's age-old yambean heritage. They should become, in other words, part of the extension agents' advisory tasks throughout the yambean zone. The goal is to stop any more farmers abandoning the crop if they don't really want to. Toward that end, other actions that can be mounted include:

- Marketing initiatives. African yambean should be quickly tested as a cash crop. In Mexico, the tubers sell for three times as much as cassava, and provide profit to farmers small and large.
- Taste tests and other popularizing activities.
- Demonstration plots. Local agronomists should undertake trials to optimize production. These would best be done in the local fields with the owner's participation—perhaps incorporating a measure of competition among, and financial reward for, the best local yambean growers. The psychology of getting the growers involved may be as important as any technical advances achieved.

Food Technology

Almost nothing is known about the basic properties of the various African-yambean foodstuffs. Investigations should now be conducted into basic features, including:

- *Digestibility and Antinutritional Factors* Trials on the actual digestibility of seeds, tubers, and forage are required. For example, alpha-amylase inhibitors in the seed could reduce caloric uptake while increasing the intestinal gases for which many beans are renowned. The challenge posed by other antinutritional factors should also be examined. In particular, the presence and fate of potential cyanogenic glycosides in both raw and cooked portions should be traced from plant to plate, just as they have been in soybean, cassava, sorghum, and other staples carrying these compounds.
- *Culinary Issues* The long cooking time is a barrier to the plant's wider use as a bean crop. Needed now is a search for the cause as well as for quicker-cooking types. As a first step, the starch in the seeds as well as the skin around them should be compared with those of other beans, such as

cowpea, common bean, and bambara bean, and correlated with the cooking time.[23]

- *Recipes* Home economics groups should involve themselves in the rescue of this ancient native. The development of dishes for both seeds and tubers is one need. Yambean tubers, for example, may well prove an attractive addition to various traditional dishes, as well as a popular snack.
- *Pods* In India, young American yambean pods are eaten like French beans. Now is the moment to test African yambean counterparts to see if they have any value as "tropical snow peas." The key is to search for and to measure the occurrence and fate of antinutritional factors such as rotenone.

Leaves The safety of eating the leaves (presumably as a boiled vegetable) deserves assessment.

Starch The chemistry of the tuber starch deserves investigation. Although it is said to be "comparable to that of cassava flour," the granules are supposedly distinctly different.[24]

Curing Tests on the storage of African yambean tubers are needed. Once the vegetative top has been removed, smallholders tend to leave the tubers in the ground until eaten or sold. The fate of the starch, protein, and other components under such treatment needs investigation. In the American species the tubers get much sweeter and more valuable when "aged."[25]

Plant Physiology This is the moment for an all-points inspection of the species itself. A plant as promising and yet as little understood as this one needs almost everything looked at. Topics needing exposure include:

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[23] Where electricity or gas is available, pressure cookers would speed up cooking and improve digestibility. Some years ago, structural changes in yambean tubers as a result of microwaving was studied. Treated tuber pieces were fed to rats and found to have a digestibility much greater than fresh tubers. Schmar, T.A., C.A.Z. Harbers, and L.H. Harbers. 1987. Structural changes in jicama (*Pachyrrhizus tuberosus*) with microwaving and digestion in rats. *Nutrition Reports International* 35(4): 771-774. Microwaving, a technology now found surprisingly often in rural Africa, also reduces antinutritional factors in many types of legumes. Hernandez-Infante, M., V. Sousa, I. Montalvo, and E. Tena. 1998. Impact of microwave heating on hemagglutinins, trypsin inhibitors and protein quality of selected legume seeds. *Plant Foods Hum Nutr* 52(3):199-208.
[24] Interestingly, the tubers of the Amazon yambean have proven to be virtually pure amylopectin, and the possibility of utilizing it in non-food products is currently being investigated.
[25] In Bolivia some producers sweeten up their tubers by putting them in a sunny place for up to 2 weeks. In a previous test, the sucrose content tripled and the starch dropped by 80 percent after 3 months of storage at 12.5°C. Paull, R.E., and N.J. Chen. 1988. Compositional changes in yam bean during storage. *Hortscience* 23:194–196.

- *Nitrogen Fixation* The efficiency of biological nitrogen fixation under both greenhouse and field conditions should be examined. Field collections of some indigenous strains of *Rhizobium* and *Bradyrhizobium* have been carried out, but the selection of genotypes and strains with high potential for nitrogen fixation still awaits.
- *Protein Chemistry* The biochemical, topochemical, and structural characterization of protein bodies of seeds and tubers need investigation.
- *Seed Features* The issues of seed set, seed size, and seed components deserve study.[26] One especial need is to check the content of rotenone in the mature and maturing seeds.[27] The different genotypes' ability to retain germination capacity during long-term storage also needs analysis.
- *Soil Requirements* Tests should be run on soils of different pH, density, and fertility levels.

Genetic Development In order for this crop to remain attractive to local farmers, improved cultivars are needed. High priority should be given to those benefiting the traditional smallholders of West and Central Africa.

The plant's dual propagation capability is a feature that will speed the process along. This is a rare crop that can be sexually propagated by seed as well as clonally propagated by tuber or root tissue. For one thing, it can be bred in the normal way using crosspollination and the resulting progeny can be multiplied clonally. This allows for flexibility, speed, and efficiency.

Genetic improvement targets of opportunity include:

- Higher yields;
- Bigger tubers;
- Seed of select colors;
- Bush-type plants that stand by themselves without staking;
- Daylength-insensitive plants that make the crop more reliable across seasons and latitudes;
- Fast maturity. Early maturing cultivars are known in yambean, and likely exist in the African form as well;
- Quick-cooking seeds;
- Lower levels of potential antinutritional factors;
- Thick-skinned tubers that don't bruise during shipping and have a long shelf life; and
- Tubers of good size and taste for consumer acceptance.[28]

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[26] In the Mexican species there is said to be a strong positive correlation between seed size and yield.
[27] Although unreported in African yambean, this alkaloid is found in the leaves and pods of New World yambeans.
[28] Consumers prefer different sizes and tastes. Mexicans and Americans, for example, demand the tubers be crunchy and juicy and weighing 0.35-0.9 kg with a sap that is

Although the above research initiatives are individually important, the ultimate target should be drought-tolerant, photothermally neutral, and pest- and pathogen-resistant cultivars capable of producing high yields and nutritious, tasty food over a wide range of climates and soils.

Exploring the Wild Resource The genetic characteristics for horticultural development highlighted above are likely present in the wild ancestor from which the cultivated form developed. They may also be present in the crop's wild relatives: *Sphenostylis angustifolia* (endemic to South Africa), *Sphenostylis briartii* (native to Congo), *Sphenostylis erecta* subsp. *erecta* (Central Africa, East Africa), *Sphenostylis erecta* subsp. *obtusifolia* (southern Africa), *Sphenostylis marginata* (southern Africa), *Sphenostylis schweinfurtii* (Central and West Africa), and *Sphenostylis zimbabweënsis* (Zimbabwe).

Sphenostylis schweinfurthii is an especially interesting species, characterized by having hairy stems and hairy leaflets that making it more resistant to drought—a feature of potential interest in breeding.

These wild relatives deserve genetic evaluation, too. Such investigations could help pin down the African yambean's ancestry. They could expose the cross-pollination success ratio, and thereby provide insight into the closeness of the genetic relationships. They could also uncover qualities that might be usefully bred into the cultivated crop.

Agronomic Exploration Although little is known about its environmental tolerances, the plant is recommended for small-scale cultivation trials in tropical regions outside its native habitat. These should be collaborative tests conducted at different altitudes, latitudes, soils, and climatic conditions, notably humid and semiarid ones. One outcome will be clarifying the plant's suspected daylength sensitivity.

Comparisons among the yambeans of commerce would also be instructive. In this regard, the African one should be put into head-to-head trials with the three New World species (and perhaps with the yam itself). The differences and similarities will teach much, to the benefit of them all.

With all the emphasis on tuber production, there has been little work on optimizing seed production. Means that have successfully increased seed yield of better-known bean crops deserve to be also applied to this species

With any viney crop the issue of plant support is paramount. It is therefore critical to rapidly test whether the African yambean really does yield tubers satisfactorily when unsupported. And if it indeed does need supports, to find the cheapest, simplest, and most effective ones.

Reproductive pruning. Because of the obvious competition between tuber

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watery rather than milky and a slightly sweet taste. Southeast Asians, on the other hand, want their yambeans 0.25-0.6 kg with a bland flavor.

growth and seed production, there is a need for field studies to clarify the effects of pruning in the more promising landraces.

Propagation In-vitro techniques are a possibility for rapidly multiplying rare genotypes for conservation purposes, or of hybrids or new material from field collections or field trials. If biotechnology can make available such genotypes in quantity, it would mean field evaluations could be made almost immediately afterwards, and especially good material could be quickly moved to growers.

Industrial Development Although today strictly a subsistence crop, the African yambean might well prove a valuable provider of industrial resources. Several products are possible on a local or sizable scale:

- *Flour* The large tuberous roots can undoubtedly be dried and ground to form a top-quality flour, useful for cakes, desserts, and other culinary purposes. The properties of this flour should be comparable to those of cassava flour, but perhaps more nutritious and profitable. In India, tubers from the Mexican yambean are ground this way and the flour is considered to be high grade.
- *Sugar* African yambean tubers need testing as a sugar source. Whether any possess practical quantities of sugar is unknown, but their cousin from the Andes (*Pachyrhizus ahipa*) has proven to contain more than twice the sugar found in sugar beet.[29]
- *Protein* Even though the protein content of the tuber is lower than that of grain-legume seeds, the total protein yield per hectare for the tubers exceeds that of soybean, the world's premier protein crop. African yambean may therefore have a future as a source of protein for people, pets, livestock, laboratory animals, and industrial processes.

Sustainable Development With its high biological nitrogen fixation, yambeans may return a substantial amount of nitrogen to the soil. The crop therefore could form an integral part of land-use systems, benefiting land and people. Programs developing sustainable African agriculture should include African yambean in appropriate trials.

In parts of tropical America, yambean plays an important role in crop rotation systems. It is grown in the same field for two consecutive seasons, producing a higher yield in the second than the first. Starting in the third season maize, beans onions, or other crops are planted there instead. Then, after a break of 3 or 4 years, yambean is returned to the field again to restore the fertility lost to the interim harvests. In Africa's generally worn-down

[29] In one test, the Andean yambean had 47 percent sugar. Sugar beet, a crop of considerable industrial importance, contains 20 percent sugar.

soils, a rotation like this might prove even more effective at sustaining land productivity.

SPECIES INFORMATION

Botanical Name *Sphenostylis stenocarpa* (Hochst. ex A. Rich.) Harms.

Synonyms *Dolichos stenocarpus*, *Vigna katangensis, Vigna ornata,Vigna ornata var. latifolia, Sphenostylis congensis, Sphenostylis ornata, Sphenostylis stenocarpa var. latifolia*

Family Leguminosae. Subfamily: Papilionoideae (Faboideae)—Pea family

Common Names

English: African yambean, otili
French: pomme de terre batéké, pempo
German: Yambohne
Ghana: kutreku, kulege, akitereku, apetreku
Nigeria: girigiri, kutonoso, roya, efik, nsama, ibibio
Malawi: cinkhoma, nkhoma
Ibo: okpo dudu
Obudu: bitei
Togo: sesonge, gundosollo, sumpelegu, tschangilu
Yoruba: sese, sheshe
Congo: giliabande, pempo, mpempo
In Africa this crop goes by a multiplicity of local names, which have yet to be systematically collected.

Description

The species is a perennial that is usually grown as an annual. The cultivated type is a twining, herbaceous vine 1 to 3 m long. The stems are strongly branched and are often reddish in color. They bear trifoliate leaves up to 14 cm long. The individual leaflets are oval with pointed tips and smooth edges.

The butterfly flowers, borne in racemes up to 30 cm long, have twisted petals 2.5cm long, and are probably insect-pollinated. The color is variable and not only includes pink, purple, and greenish white, but also yellowish white, red, magenta, lilac, and blue.

Most blooms develop into narrow pods, 20 to 30 cm long and about 1 cm wide. They are pointed and are subdivided inside by fine transverse walls. The ripe ones are brownish in color and up to 30 cm long. They contain 20-30 seeds. The seeds themselves are large (up to a cm long) and can vary from white to brown and black. Some are speckled or marbled in brown and white, and there veined seeds are known as well. The hilum has a brown

border.

The root system typically branches vigorously. However, some roots thicken into the storage organs. These spindle-shaped tubers outwardly resemble sweet potatoes but taste more like potatoes. In general, they are from 5 to 25 cm in length and weigh 50-300 g (average 250 g). The smallest are normally kept aside and used for planting the next crop.

Distribution

Within Africa Although African yambean is obscure in a general sense, it exists in a number of countries. In broad terms, the cultivation area extends from tropical West Africa to Sudan, Eritrea and northern Ethiopia. From there it extends southward to Congo in the west and Zanzibar in the east. However the greatest importance, without a doubt, is in West Africa, primarily Nigeria and its immediate neighbors.[30]

Beyond Africa At the time we write this, the plant seems unknown outside Africa.

Horticultural Varieties

Only local landraces are grown, though some accessions are named.

Environmental Requirements

Although little is known about its needs, a humid tropical climate with well-drained soil seems necessary or at least best.

Rainfall According to claims in the literature, the crop requires between 900 and 1,400 mm annual precipitation.

Altitude Seemingly little affected by altitude, it flourishes at elevations from sea level to 1,800 m.

Low Temperature Almost certainly sensitive to frost.

High Temperature The limit is unreported. Good growth is possible between 19 and 27°C.

Soil Type The crop is mostly cultivated on poor soils. Its optimal

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[30] Overall, the species has been found (wild and/or cultivated) in the following countries: Angola, Burundi, Cameroon, Central African Republic, Chad, Congo, DR Congo, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

substrates are said to be weakly acid, with pH 5 to 6. The site should be well drained. Fertile sandy soils are said to be "highly suitable."[31]

Related Species

The African yambean is so closely related to *Vigna* species that a botanist once classified it as *Vigna ornata*. This genus—an important one for food in the tropics—includes moth bean, mung bean, bambara bean, rice bean, cowpea, and adzuki bean. Modern techniques, including embryo rescue, might allow the production of interspecific hybrid combinations between it and the other two cultivated species. This suggestion is a stretch, but if it proves possible the resultant plants could be particularly valuable in developing cultivars that are early maturing, heat- and day-length neutral, bushy, and better adapted to new areas.

[31] Root crops typically yield worst in heavy soils that confine the tubers and keep them from swelling.

Appendix A

BIOGRAPHICAL SKETCHES OF PANEL MEMBERS

Dr. Norman Borlaug, Chair, is Senior Consultant to the Director General of CIMMYT (International Maize and Wheat Improvement Center), as well as Distinguished Professor of International Agriculture at Texas A&M University, and President, Sasakawa Africa Association. A Member of NAS (1968), Nobel Peace Laureate, and Founder of The World Food Prize, he is the recipient of nearly 60 honorary degrees. Dr. Borlaug's early work in plant pathology, wheat breeding, and agronomic systems has since led him to become one of the best-known spokespersons and ambassadors for tropical agriculture and food security. He has been particularly influential at engaging political leadership to integrate agricultural policy into national planning. Dr. Borlaug has had a broad impact on global agricultural research and production, has helped train a generation of agricultural scientists, and remains deeply involved in enhancing African agriculture through the Sasakawa Africa Association and its Global 2000 Partnership with the Carter Center, whose mission is raising the productivity of African farmers through sustainable development and equitable and responsible use of resources. Borlaug is from the U.S., and has a doctorate in plant pathology from the University of Minnesota.

Dr. Anthony Cunningham, Director of Ethnoecology Services in Fremantle, works predominantly with the WWF/UNESCO/Kew "People and Plants Initiative", which he helped found and for which he worked as African Regional Coordinator from 1992 through 2000; he is also engaged by the Centre for International Forestry Research. An ethnoecologist whose work focuses on the applied ecology of natural-resource use by people, his early research was on traditional foods in southern Africa. He has since worked across the continent (and elsewhere) investigating the interactions of humans with their environment by examining, especially, field management of useful plants. With his focus on the relationships among agriculture, resource exploitation, and conservation, much of his research has been tied to

implementation processes promoting collaborative resource management programs between local communities and outside influences such as government, NGOs, and conservation or commercial interests. Among other awards, he has received the occasional Sir Peter Scott Award for Conservation Merit from the IUCN Species Survival Commission (1999), and the EK Janaki Ammal Medal (2002) from the Indian Society of Ethnobotanists for significant contributions and achievements to the field. Cunnningham is from South Africa, and has a doctorate in botany from the University of Cape Town.

Dr. Jane I. Guyer is currently Professor of Anthropology at Johns Hopkins University, after moving in 2002 from Northwestern University where she had been Professor of Anthropology and Director of African Studies since 1994. Professor Guyer, a Woodrow Wilson Fellow in 2003, specializes in African studies, social anthropology, and the study of production and distribution systems, in particular the anthropology of the economy and material life in West and Equatorial Africa. She focuses primarily on the growth and change of indigenous economies, with a special emphasis on food economies and money management outside structured systems. Professor Guyer has authored and co-authored numerous books and articles; her most recent single-authored book is *Marginal Gains: Monetary Transactions in Atlantic Africa*, which focuses on the function of popular economic systems in Africa, from crisis conditions to ordinary household budgets. Guyer, a U.S. citizen, is from England, and has a doctorate in anthropology from the University of Rochester.

Dr. Hans Herren has been President of the Millennium Institute since 2005. Dr. Herren earlier served as Director General of the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi for twenty years, prior to which he was with the International Institute of Tropical Agriculture. He is an NAS Foreign Associate (1998), and President of the International Association for the Plant Protection Sciences. An agronomist and entomologist, Dr. Herren has spent most of his working life in Africa, where his research has been on the field-level union of science-led information with local production systems, particularly emphasizing pioneering applications of integrated pest management. His latest research efforts address poverty alleviation, sustainable agricultural productivity, and biodiversity conservation in Africa. Herren's contributions to improving Africa's food security, particularly research and control of the cassava mealybug through the world's largest biological control project, have been recognized through many awards,

including the Tyler Prize for Environmental Achievement and World Food Prize "in recognition for having advanced human development by improving the quality and availability of the world's food supply". Dr. Herren also currently serves as the Editor-in-Chief of the ICIPE-hosted journal, *Insect Science and its Application*, and is on the Editorial Board of *Biological Control Science*. Herren is from Switzerland, and has a doctorate in agricultural sciences from its Federal Institute of Technology.

Dr. Calestous Juma is Professor of the Practice of International Development and Director of the Science, Technology and Globalization Project at the John F. Kennedy School of Government at Harvard University. He is a Member of NAS (2005), and has served on many NRC committees. He is also a Member of the Kenya National Academy of Sciences and a Fellow of both the New York Academy of Sciences and the World Academy of Art and Science. Dr. Juma is former Executive Secretary of the United Nations Convention on Biological Diversity and founding Executive Director of the African Centre for Technology Studies in Nairobi, an independent public policy research institution. His research interests, beginning with field work with indigenous vegetables in Kenya, include biological diversity and biotechnology, evolutionary and systems theory, science and technology policy studies, institutional change, and international trade and international environmental policy. He has worked as a teacher, science writer, chief executive officer, and advisor (including USAID), has served on the governing and advisory bodies of several international organizations, and has won many international honors. Dr. Juma has written widely on issues of science, technology and environment, including *Science, Technology and Economic Growth: Africa's Biopolicy Agenda for the 21st Century*. United Nations University, Tokyo (2000). Juma is from Kenya, and has a doctorate in science and technology policy studies from the University of Sussex.

Dr. Akinlawon Mabogunje was Chair of the Development Policy Centre in Ibadan, Nigeria until retirement, and serves as co-convener of the international Initiative on Science and Technology for Sustainability. He is also Chairman of the Nigerian Presidential Technical Committee on Housing and Urban Development. He was formerly Professor of Geography, Dean of the Faculty of the Social Science, and Director of the Planning Studies Programme, University of Ibadan, and was also President of the International Geographical Union. He is an NAS Foreign Associate (1999) and is currently a Member of the Committee

on the Geographic Foundation for Agenda 21. He also served as Chairman of the Committee on Human Settlements of the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions. In addition, he was Chairman of the Advisory Committee of the Urban Management Programme of the United Nations Centre for Human Settlements/United Nations Development Programme and the World Bank, was Vice-Chairman of the Directorate of Food, Roads and Rural Infrastructure, Office of the President, Nigeria, and Executive Chairman of the National Board for Community Banks. Dr. Mabogunje's work seeks to understand continuity and development of rural/urban/regional interactions in Africa over time, with increasing attention to future issues of sustainability. These interactions are especially close in Africa, and his research on the relative contributions of internal and external systems affecting them have recast many assumptions underlying development there. In particular, his work has called attention to the persistence of indigenous structures whose better understanding and utilization can help to more effectively unleash development energies of the people, especially in the rural areas. Among his many published books and academic papers are *Urbanization in Nigeria, Regional Planning and National Development in Africa; The Development Process: A spatial perspective*; and (as editor) *The State of the Earth: Contemporary Geographic Perspectives*. Mabogunje is from Nigeria, and has a doctorate in geography from University College London.

Dr. Barbara Underwood, Adjunct Professor of Nutrition (in Pediatrics) at Columbia University, was until recently Scholar in Residence at the U.S. Institute of Medicine, and is the Immediate Past President of the International Union of Nutritional Sciences. Prior to retirement she was Chemist at the National Eye Institute of the U.S. National Institutes of Health, where she also served a secondment as Scientist in the Nutrition Unit of the World Health Organization. Dr. Underwood has broad field association with the great variety and analyses of foods eaten by humans, with 40 years global experience in research and training related to international nutritional deficiency and maternal/child health problems, with recent years devoted to development of global policy and guidelines for the control of micronutrient deficiencies of vitamin A, iron, and iodine. Her work is based on the interactions among food, nutrition, and health in developing countries, with research interests emphasizing studies on vitamin A metabolism, nutritional status assessment, and functional consequences of deficiency. Her laboratory developed and first applied in human populations the Relative Dose Response (RDR)

test to indirectly identify depleted vitamin A stores. In addition, her research and training interests have focused on nutritional problems of mothers and children in deprived circumstances, and she has more than 150 publications in basic and applied nutrition and nutritional biochemistry. Dr. Underwood has served on many international committees, advisory and editorial boards, and consultancies, including USAID, as well as board member of numerous foundations and advisory groups. Underwood is from the U.S., and has a doctorate in nutritional biochemistry from Columbia University.

Dr. Montague Yudelman has been a Senior Fellow at the World Wildlife Fund for Nature (WWF) in Washington, and is a Woodrow Wilson Fellow. He has been involved in international agricultural development for close to 50 years. He was on the staff of the Rockefeller Foundation during the gestation of their international agricultural research program, and later, as the director of Agriculture and Rural Development at the World Bank, he was involved in the planning for and creation of the Consultative Group on International Agricultural Research. Dr. Yudelman retired from the Bank in 1983, and was a Distinguished Fellow at the World Resources Institute prior to affiliating with WWF. He has also taught at Harvard University and the University of Michigan, and served as Vice President of the OECD Development Center. He was Chair of the Board of Trustees of the Population Reference Bureau, and serves on the Board of The Vetiver Network among other organizations. Dr. Yudelman has consulted to numerous institutions, including the Inter-American Development Bank, USAID, the Rockefeller and Ford Foundations, and several foreign governments. He has published widely in the field of agricultural development, food production, and pest management, including the 1964 standard, *Africans on the Land*; recent publications include IFPRI's 2020 Vision Discussion Paper #32, *Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges* (with Peter Gruhn and Francesco Goletti), 2000, and the concluding chapter, "Agricultural Research in the Tropics: Past and Future", in ISNAR's 1997 expanded edition of *The Globalization of Science: The Place of Agricultural Research*. Yudelman, a U.S. citizen, is from South Africa, and has a doctorate in agricultural economics from the University of California at Berkeley.

Appendix B

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Pliny the Elder, after Aristotle